STUDIES ON SOME ASPECTS OF BIOLOGY AND ECOLOGY OF CORAL REEF FISHES OF LAKSHADWEEP WITH OBSERVATIONS ON OTHER CORAL REEF ECOSYSTEMS IN THE SEAS AROUND INDIA

THESIS SUBMITTED

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BY

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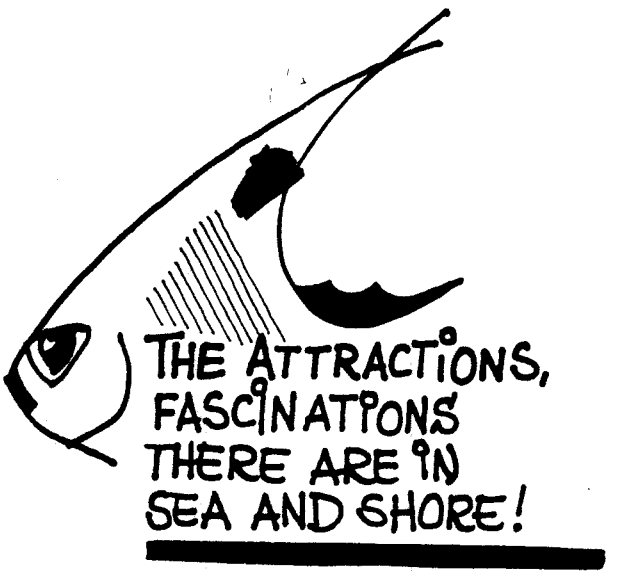

WITH LOVE TO MUM, DAD
ELIZABETH & RACHEL

DECLARATION

I hereby declare that this thesis entitled **"Studies on some aspects of biology and ecology of coral reef fishes of Lakshadweep with observations on other coral reef ecosystems in the seas around India"** is a record of original and bonafide research carried out by me under the supervision and guidance of Dr. N.G.K. Pillai, Senior Scientist, Central Marine Fisheries Research Institute, Kochi, and that no part thereof has been presented for the award of any other degree, diploma, associateship, fellowship or other similar recognition.

Kochi
May, 1994

P. Emmanuel Vijay Anand.
P. EMMANUEL VIJAY ANAND

CERTIFICATE

This is to certify that this thesis entitled **"Studies on some aspects of biology and ecology of coral reef fishes of Lakshadweep with observations on other coral reef ecosystems in the seas around India"** is an authentic record of the research work carried out by P. Emmanuel Vijay Anand under my supervision and that no part thereof has been presented for the award of any other degree.

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PREFACE

The prelude for this study was an investigation conducted by me in 1988 - '89 on the bionomics of three marine ornamental fishes from Lakshadweep which emboided results of research mainly concerning biological aspects of feeding and reproduction. Motivated by the richness of reef fishes, their fascinating relationships evident from casual observations and from the basics obtained previously, it was considered desirable to undertake investigations on a broader scale which might open up a nearly dormant field of fisheries science in India.

Based on evidence obtained from an ever-increasing literature on ecological studies of coral reef fishes, it is obvious that this important aspect of coral reefs has made immense strides in the past 30 years, but India faces the stupendous task of bringing out an understanding on this subject.

With experience in foreseeing current needs in fisheries research, Dr. P.S.B.R. James (Director, CMFRI) and Dr. N.G.K. Pillai (Senior Scientist and Supervising Guide) were instrumental in analysing the programme of research that laid special emphasis on the fishes of coral atolls of Lakshadweep with few observations on processes of other coral ecosystems of the country. Despite constraints in the availability of equipment for field work and to an extent, current literature,

the present study has made use of locally generated help and equipment with respect to boats, out-board engines, various fishing gear, field help, accomodation and food.

Though there have been studies on systematics of corals, aspects of geology, hydrography, live bait fish and tuna fisheries, detailed investigations on fishes associated with coral reefs are mainly restricted to accounts on systematics and just a handful of short term studies on biology and ecology. Coral reef fish not only form an important food source produced either through capture or culture procedures but also find their way into conservation and management by serving as early-warning mechanisms for deleterious environmental changes. Further, coral reef fishes have become increasingly popular as marine ornamental fishes in the recent years and are capable of earning foreign exchange for the country. In view of their importance, detailed understanding of their biology and ecology is essential.

The present study entitled, **"Studies on some aspects of biology and ecology of coral reef fishes of Lakshadweep with observations on other coral reef ecosystems in the seas around India"** for which data were collected from January 1991 to June 1992, provides information on aspects of fish habitats, species composition on reef systems, community organisation, food habits and reproduction of some common fish species. As methods of harvest play an important role in obtaining fish resources, they are briefly described to suggest further improvements. This study is expected to lay the foundation for future research on this subject.

The thesis is organised into seven chapters of which six of them follow a conventional style of presentation, each with a short introduction followed by review of literature, material and methods results/observations and a discussion. The discussion in Chapter III is divided into two parts corresponding to the two aspects of community organisation viz., families and species. Chapter VII is non-conventional, outlining various practical uses of the results of the present study. A general introduction, summary and references are also included.

I am grateful to Dr. P.S.B.R. James, Director, Central Marine Fisheries Research Institute (CMFRI), Cochin during whose tenure this work was initiated and carried out; and for providing all necessary facilities, general guidance and advice. I wish to express my gratitude to Dr. N.G.K. Pillai, Senior Scientist and Research Guide for all encouragement, guidance and help extended to me through the period of study. I am also grateful to Dr. P.V. Rao, Acting Director, CMFRI and Professor Shahul Hameed, Head, Department of Industrial Fisheries, Cochin University of Science and Technology for encouragement and advice. I sincerely thank Dr. V. Sriramachandra Murty, Senior Scientist, CMFRI for critically reviewing Chapter II.

I am grateful to the Indian Council of Agricultural Research (ICAR) New Delhi for the award of Senior Research Fellowship and Cochin University of Science and Technology, Cochin, for providing the studentship for doctoral research. I also thank immensely, the

Administrators of the Union Territory of Lakshadweep, Shri. Aggarwal and Shri. Satish Chandra for granting permission and providing facilities for research on the islands; the friendly people of Lakshadweep for their active involvement and co-operation; the Central Agricultural Research Institute, Port Blair, Andamans, the Central Aquatic Sciences Research Institute, Okha, Gujarat and the Regional Centre of the Central Marine Fisheries Research Institute, Mandapam Camp, Tamilnadu for local assistance.

Kochi,
30.05.1994.

P. EMMANUEL VIJAY ANAND

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A great deal of field work and data collection for this study in the four major coral reef ecosystems of the country were carried out with the spontaneous help, kind gesture and wholehearted cooperation of several individuals, departments and institutes. I express my deep sense of gratitude and indebtedness to all of them specially mentioned below for inspiring and encouraging me to successfully complete this study.

LAKSHADWEEP: Maintenance of laboratory, boats, nets, field work and round-the-clock assistance: Habeeb Rahman; Stay and travel permit: Lakshadweep Administration, Dept. of Fisheries, Kavaratti; Accommodation: Staff of SPORTS, Kasali, Cheriyakoya, Komalam house; Operation of fishing gear, boats and fish collections: Habeeb Rahman, Jaleel, Mohammed Ali, Hameed, Hidayat, Mohammed, Ayub, Sarath, Yakoob, Kabeer, Mohammed Ali, Hussain, Davood, Aboobaker, Moosa, Ibrahim, Thangakoya, Jaffer, Kasi, Shaffi, Zaccariah; Boats and outboard motors: Nehru Yuva Kendra - Kavaratti, SPORTS - Kavaratti, SPORTS - Kalpeni, Hassan, Syed Ali, Basheer, Jaffer; Assistance during censuses: SPORTS - Kavaratti, Habeeb Rahman, Jaleel, Mohammed Ali; Local transport: Jaleel, Syed Ali; Helicopter service: Pawan Hans Ltd., Capt. Sandhu, Capt. Balla; Other help - other islands: Dept. of Agriculture, Central Library, Dept. of Fisheries, SPORTS, Moosa, Haneefa, Shaukat, Raghavan, Shanmugham, Ahmed, Kandan, Nasser.

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CONTENTS

INTRODUCTION

Coral reef science is now largely diversified into specialized fields in the tropics where most of the reefs are situated. The current concern on the world's coral reefs is to maintain ecological 'health' and sustainable yields of harvestable organisms. In comparison to reef-related research from other developing countries and in the context of need for specialized data, the progress in India has rather been tardy. Scanty but important studies are those on systematics of corals, associated fishes, invertebrates and hydrographic surveys. In the meantime, certain Indian reef systems (e.g., reefs of the Gulf of Kutch) have degenerated beyond recovery despite the existence of conservational measures that were perhaps not enforced strictly. There is an overall paucity in reef-related studies that could make available basic data and create environmental awareness among planners and users.

The ignorance of the importance of coral reefs as a heritage is slowly leading towards the creation of 'ill health' of valuable ecosystems through unplanned and environmentally non-friendly development. Nevertheless, unlike the Gulf of Kutch reefs, the other three major reef

systems, viz., of Lakshadweep, Andaman and Nicobar Islands and Gulf of Mannar are relatively in a better 'health' primarily because these ecosystems are not easily accessible to man as they are separated by varying expanses of seas around India. From this background, it is evident that the first, quick step to be taken is the procurement of basic data from all specialized fields of coral reef science for evolving guidelines for development.

Fishes are the most conspicuous organisms of a coral reef ecosystem. Sale (1991 a) in a most recent review on the ecology of fishes on coral reefs stated that publications on coral reef fishes date from the mid-and late-1950s, while the interest exploded during the 1960s and 1970s. Four significant reviews that appeared ever since were those of Ehrlich (1975), Goldman and Talbot (1976) Sale (1980 a), and Doherty and Williams (1988). However, Indian contribution in this field is very insignificant. The most comprehensive account on reef fishes was that of Jones and Kumaran (1980) in which 603 fish species of the Laccadive Archipelago were described. Important descriptions of reef fishes inhabiting other coral reef ecosystems were by Day (1878), Herre (1938), Chhaya and Patel (1978) and Talwar and Kacker (1984). However, there is evidence that many more reef fishes are yet to be adequately described.

In comparison to taxonomic work, studies on the ecology, biology and distribution of coral reef fishes are just a few from Lakshadweep (Ayyangar, 1922; Jones and Kumaran, 1964; Pillai et al., 1984, 1986, 1987, 1990, 1992, Madan Mohan et al., 1986; Madan Mohan and Kunhikoya, 1986;,

Kumaran et al., 1989; Murty et al., 1989; Vijay Anand 1990 a; Vijay Anand and Varghese 1990, 1992 a & b; Suresh 1991) and only three from Andaman Islands (Rangarajan 1970, 1971 and 1972). Except for a report on perch fishery by special traps from the Gulf of Mannar region, where few aspects of the biology of reef fish were dealt by Prabhu (1954), there have been no studies from this region and also from the Gulf of Kutch.

Munro (1984) stated on a world-wide basis, coral reef fishes are underexploited. Coral reef fishes are among the major exploited fish resources from reefs (Salm, 1988) which are recently picking up excellent market value (Nicoll, 1993). As evidenced by a very low fishing activity on Indian reef systems, coral reef fish resources that can earn valuable foreign exchange through export remain underexploited. Certain coral reef fishes (e.g., groupers) also form ideal candidates for cage culture, while a majority of small species have become popular marine ornamental fishes. In the late eighties, the world trade in ornamental fish, associated plants and accessories stood at US $ 7.2 billion (Andrews, 1992). With an exception of a few southeast Asian countries, ornamental fish trade in the developing countries is unsatisfactory mainly due to lack of technical know-how (Vijay Anand, 1993).

Philippines, Sri Lanka, Singapore are among the largest suppliers of marine ornamental fishes to the world's markets. Tomey (1985, 1986) conducted and assessed the Indian potential for ornamental fish export but the country, despite enormous scope for development of the trade, has not made any progress in the field ever since. This is possibly due to lack of basic information on such fishes. Further, coral reef fishes are also

used to serve as early-warning mechanisms of a deleterious environment (Reese, 1978, 1981). In view of the high fisheries potential of coral reef fishes and inadequate attention paid to their exploitation and utilization in comparison to other fisheries resources in the country, the present study was taken up to generate data and information on coral reef fishes with special reference to Lakshadweep from January 1991 to June 1992. The field observations and collections were mainly made on the Kavaratti atoll. Data were also collected from other islands of Lakshadweep as well as Andaman Islands, Gulf of Mannar and Gulf of Kutch. The data presented in the thesis lays a foundation for economic utilization and management of coral reef fisheries resources.

Previous experience of the present investigator on studying the bionomics of three ornamental fishes of Lakshadweep (Vijay Anand, 1990 a) has brought to light that community-level studies of current importance are particularly useful in understanding the fish assemblages with space and time. Therefore, in the present study, an attempt has been made to document the relationships of coral reef fish with sets of habitats on Kavaratti atoll, Lakshadweep, thus marking a beginning of studies on the community organisation of fishes on coral reefs in India. As coral reef fishes are intimately attached to their specific habitats, it was a necessary prerequisite to classify sub-habitats based on either physical or biological characters. Habitat studies are not only important in studying fish assemblages but also help in understanding the status of various reef systems. Therefore, sub-habitats have been described from all major reef systems. Similarly, as a comprehensive list of fish species belonging to

families that are characteristically associated with all the coral reef systems studied here is not available, the same is provided for the first time.

Though studies on food and feeding and aspects of reproduction are conventional, their application to multispecies coral reef fish populations alter certain traditional assumptions. For example, certain zooplanktivores show a carnivorous mode of feeding and certain carnivores on coral reefs are benthic invertebrate feeders. Some omnivorous species show a tendency towards zooplanktivory. Similary, reproductive strategies adopted by reef fishes are equally diverse and complicated due to occurrence of hermaphroditism, protandry, protogyny etc. Equally complex are juvenile fish settlement strategies, their habitat requirements and migrations. Therefore, the need to study this unique population of fishes in order to understand their basic life cycles and develop competency to advise fishermen and aquaculturists to increase production through reduction of production costs and maximising conservation of stock lead to an investigation of food habits and reproduction of these fishes.

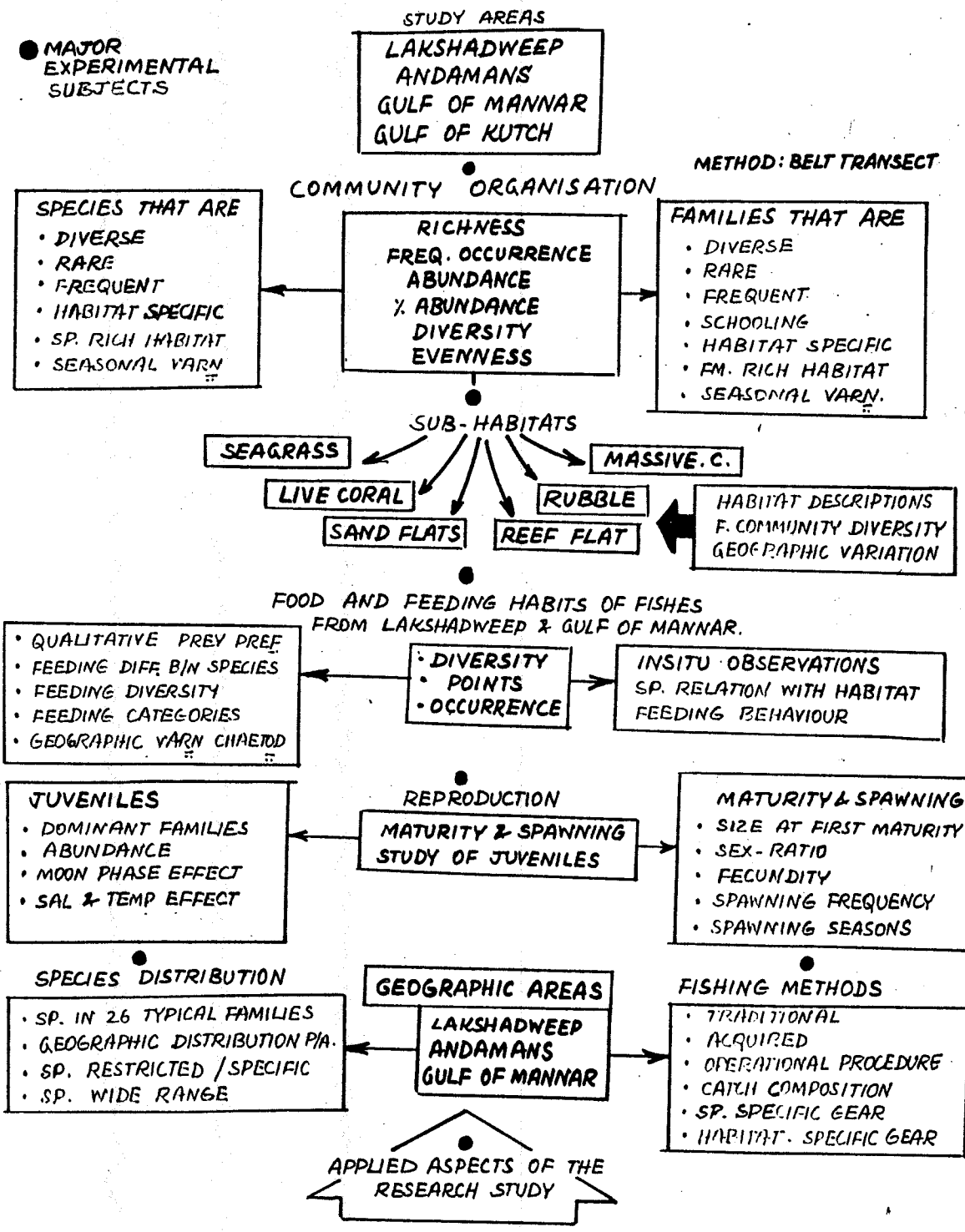
As fish form the major food resource on coral reefs and are also in increasing demand as aquaculture species and ornamental fishes, it was considered essential to acquire knowledge of their methods of capture, which would form a basis for improving traditional methods either to enhance fish production or capture fishes without damage for captive purposes.

The study specially focussed attention on derivation of information based on the results of research regarding the various fish resources which can be exploited, their seasons, abundance and areas of occurrence; fishing methods and improvements or selection of appropriate gear; species and area suitable for seafarming; identification of species suitable for ornamental fish trade; formulation of artificial feeds and development of attractants in feeds; measures for conservation and protection of both the fish and their habitats.

The plan of the present work is shown in the accompanying chart. All figures and color photographs contained in this thesis are by the investigator.

It is hoped that this study would stimulate further research generating facilities for extensive studies on all coral reef ecosystems in the country.

RESEARCH PLAN



SUPERVISING GUIDE
DR. N.G.K. PILLAI, CMFRI

NOVEMBER, 1990.

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P.E. VIJAY ANAND.

CHAPTER I

MAJOR INDIAN CORAL REEFS AND DESCRIPTION OF THEIR SUB-HABITATS

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INTRODUCTION

Three basic reef types viz., fringing reefs, barrier reefs and atolls with modifications are represented in India. Coral reef heritage is composed of reef systems that are set apart geographically and vary with regard to reef types and formation. The oceanic reef systems are represented by Lakshadweep (atolls) and Andaman and Nicobar Islands (fringing reefs). The submerged discontinuous barrier reef in the Gulf of Mannar and the fringing reefs at Gulf of Kutch are examples of continental reef-systems.

The present state of coral reefs in India potrays, ill health in some regions. Subjected to severe damage beyond recovery are reefs of Gulf of Kutch. Due to recent restrictions laid upon human interference on

reefs of Gulf of Mannar, reef health is in a better position. The reefs are relatively in good condition in Lakshadweep and Andaman Islands probably due to the fact that they are well separated from mainland thus reducing chances of intereference. Areas with patchy coral growth are reported from along the East and West coasts of mainland but are probably not of high reef forming magnitude.

There have been relatively few detailed studies on coral reefs of India, in comparison to research activities on reef areas of developing countries. Studies conducted so far were mainly on systematics of corals, aspects of geology and hydrography. Scanty information on other fields of coral reefs need supplementation. The present investigation emphasises the 'zonation' aspect from representative areas of Indian coral reefs. As coral reefs at smaller scales, offer a series of habitat zones distinctive of their physical features and biological associations, classification and description of sub-habitates provide a basis for comparing various ecological processes, in this case being the habitats for coral reef fishes.

MATERIAL AND METHODS

General description of the major coral reefs is fairly well documented, nevertheless a brief account on each is provided. Information on physiographic zonation of Indian coral atolls is absent while atolls of Maldives (Addu atoll) are described in detail (Davies,

et al., 1971; Soddart,1973). General zonation patterns on the atolls of Lakshadweep are described from observations underwater (by snorkeling) from the surface (glass bottomed boat) and aerially (helicopter).

The study areas surveyed are given in Figures 1 to 7. A variety of habitats occur on coral reefs that form specific feeding or shelter sites for coral reef fishes. The sub-habitats have been classified mainly based on physiographic and biological characters. All underwater observations were made using the snorkel apparatus. Identification of biological constituents of the sub-habitats was made upto specific level to the extent possible. Photographs pertinent to each area are provided.

REVIEW OF LITERATURE

Coral reefs of the Indian Ocean were reviewed by Stoddart (1972, 1973) and the South Indian sand cays (Gulf of Mannar) were described by Stoddart and Fosberg (1972) Silas et al. (1985) reviewed the existing and proposed Marine parks and reserves in India. Fosberg (1976) gave an account on coral island vegetation. Information on corals and coral reefs of India was summarised by Wafar (1986).

Most of the information from Lakshadweep is concentrated around the southernmost atoll in the group-Minicoy. First reports are of Gardiner (1901) with descriptions on various profiles of Minicoy atoll. Lakshadweep Islands were described as remains of eroded atolls which

probably is not true (Alcock, 1902). In 1903, the fauna and geography of the Maldive and Laccadive Archipelagoes have been described by Gardiner, while coral formations were described in 1903. Ellis (1924) provided a short account on Laccadive Islands and Minicoy. Mallik (1979) summarised studies concerning coralline deposits and some biological aspects of Kavaratti and Kalpeni atolls, Lakshadweep. The presence of four major biomorpholoqical zones with regard to molluscan assemblage were identified on Kavaratti atoll (Namboodri and Sivadas, 1979). The endangered marine and terrestrial habitats of Minicoy have been described by Pillai (1983 a). Sivadas et al. (1983) documented existing types of vegetation on Kavaratti Island while Anon (1984) described the aesthetic value of Lakshadweep as 'The coral paradise'. Geology of Kavaratti and Kalpeni atolls was studied by Mallik (1985 b) and general features of Lakshadweep were accounted by Jones (1986). The ecological stress in Minicoy lagoon and its impact on tuna bait fishes was described by Pillai and Madan Mohan (1986), while Pillai (1986) gave an account of the status of coral reefs in Lakshadweep. Environmental damage and its consequences were studied by James et al. (1989) and detailed underwater observations were carried out on 11 atolls and one submerged reef (supporting an island-Androth) by Victor et al. (1989). Various zones and sub-habitats on coral reefs were described in connection with studies on coral reef fishes of Lakshadweep by Vijay Anand and Vārghese (1990a, 1992b). Aspects of geology, geography, environmental features etc. of five atolls were described by Vadivelu et al. (1993) in a report on soils of Lakshadweep.

General topographical features of Andaman and Nicobar Islands were given by Kloss (1902), and the nature of sea bottom of shallow areas inhabited by Trochus niloticus was described by Rao (1937). Information on land and shoreline reliefs was accounted by Elliot (1972). Coral reefs of the Andaman and Nicobar have been studied by Reddiah (1977). An account of mangroves was given by Gopinathan and Rajagopalan (1983), while topographical features were described by Mahadevan and Easterson (1983). Data on reef ecology and distribution was given by Pillai (1983 b). Endangered coral reefs of the Bay Islands and their ornamental fishes were described by Arif et al. (1987). A status report on corals of Andaman and Nicobar Islands gives information on formation, zonation and coral species occurring in the area (Dorairaj et al. 1987). Acharya (1993) detailed the irrevocable damage indiscriminate exploitation can cause to coral reefs of the Andaman and Nicobar Islands.

Distribution of corals on a reef at Mandapam (Palk Bay) was studied by Pillai (1969). The characteristics of the fringing reef around Appa Island in the Gulf of Mannar have been described by Reddiah (1970), while underwater surveys were conducted to mark the extent of coral reefs around Gulf of Mannar Islands (Rajendran and David, 1972). Pillai (1973) described the coral reef resouces of Palk Bay and Gulf of Mannar. Mergner and Scheer (1974) gave an account of the physiographic zonation and the ecological conditions of some south Indian and Ceylon reefs. A team of experts from Central Marine Fisheries Research

Institute, Cochin, surveyed 21 Islands and reef formations in the Gulf of Mannar for setting up of a marine national park (Silas et al., 1977). Various structural components of some algal beds among coral islands in Gulf of Mannar were described by Subramanian et al. (1985). Detailed work on zonation from the area has not been conducted so far.

Earliest report on marine zoology from the Gulf of Kutch area is that of Hornell (1909). N.I.O. (1978) reported about the status of Pirotan Island for implementation of conservation plans, while Pillai et al. (1980) surveyed the major coastal and marine ecosystems in the Gulf of Kutch. Mangrove ecosystems in the region were studied by Chavan (1985). Existing patchy corals in Kutch area are known to be gradually diminishing (Patel, 1985), while the Gulf of Kutch has been referred to as a marine paradise (Rashid, 1985). Satellite data were applied to monitor degradation of tidal wetlands in the region by Nayak et al. (1989). There have been relatively few reports about habitats in the Gulf of Kutch region as most of the work was centered around Gulf of Mannar reefs and Minicoy atoll (Lakshadweep) where facilities exist.

OBSERVATIONS

A. MAJOR INDIAN CORAL REEFS: The study areas in the present investigation are grouped into two main categories, namely the oceanic reef and continental reef systems. The former comprises of a chain of coral atolls of Lakshadweep in the Southern Arabian Sea and the Andaman and Nicobar Islands with fringing reefs in the eastern Bay of Bengal.

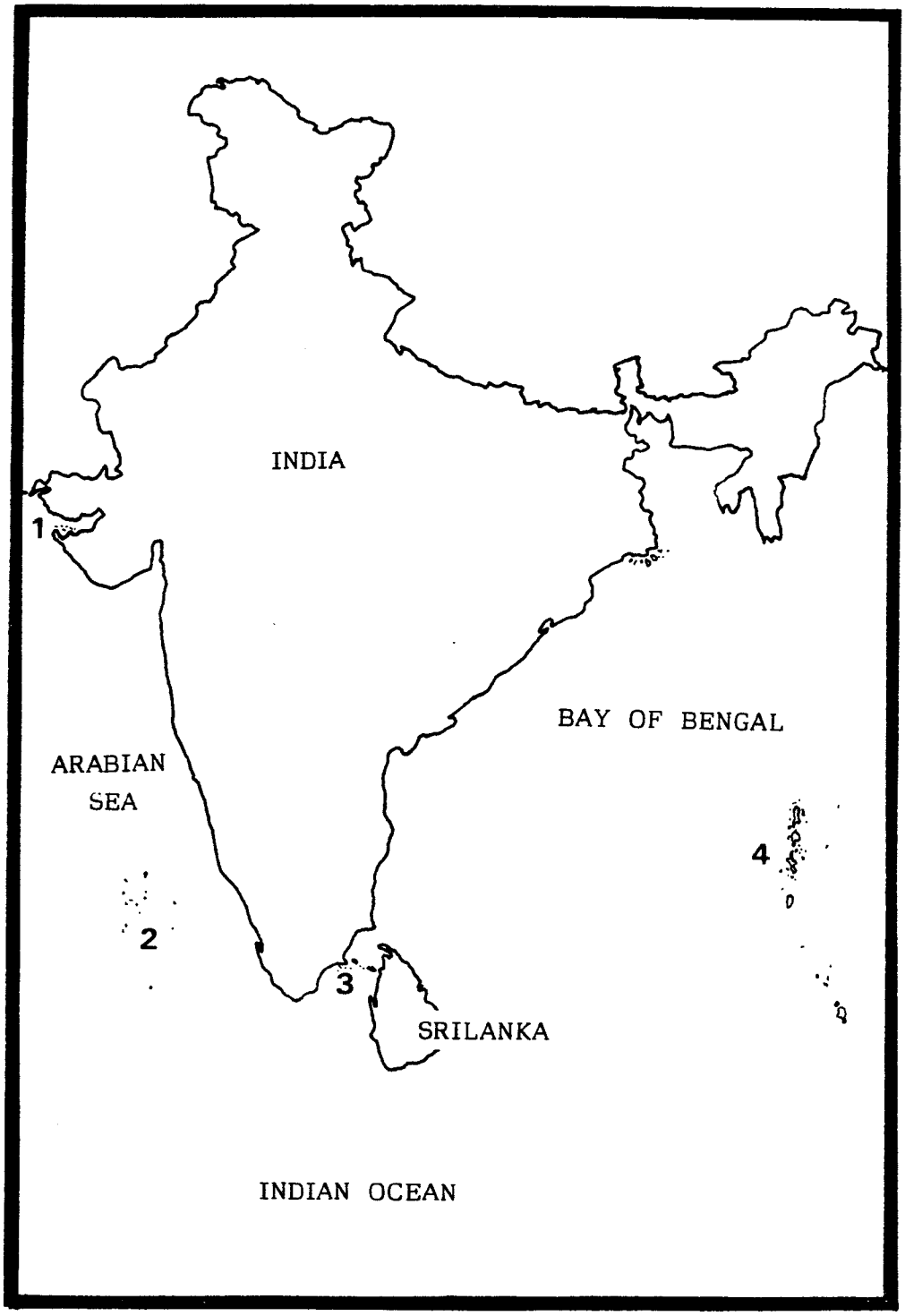


Figure 1. The major coral reef ecosystems of India.

1. GULF OF KUTCH
2. LAKSHADWEEP
3. GULF OF MANNAR
4. ANDAMAN AND NICOBAR ISLANDS

Continental reef systems are situated close to the Indian subcontinent. The two major reef areas are situated around a series of small islands supported by a submerged barrier reef in the Gulf of Mannar (between the Indian mainland and Sri Lanka) in the Bay of Bengal and the fringing reefs of Gulf of Kutch in the north-west, in the Arabian Sea (Fig. 1).

1. Coral atolls of Lakshadweep: Lakshadweep forms the northern part of the Laccadive - Chagos Ridge in the Arabian Sea, 200 to 400 km off the coast of Kerala State (8 to 12°N and 71°45' to 73°45'E). It consists of 11 major atolls (Agatti, Amini, Bangaram, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan, Minicoy and Suheli), four major submerged reefs (Androth, Beliapani, Cheriyapani and Perumul Par) and five major submerged banks (Bassas de Pedro, Sesostris, Coradhiv, Amini - Pitti and Elikalpeni). Nine of the atolls, namely, Agatti, Amini, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy are inhabited. Among the submerged reefs only Androth supports a large vegetated island and is inhabited (Fig. 2).

Most of the atolls (Fig. 3) have a NE-SW orientation with large shallow lagoons on the western side (windward) and coconut palm - vegetated islands on the eastern fringe of the atoll (leeward). Only Kiltan and Bitra have a slight NW-SE orientation. Bangaram and Suheli differ from other atolls with regard to the position of the islands. Bangaram Island (Photo 1) is situated centrally in the lagoon. Tinnakara is also situated in the lagoon but towards the eastern edge of the reef.

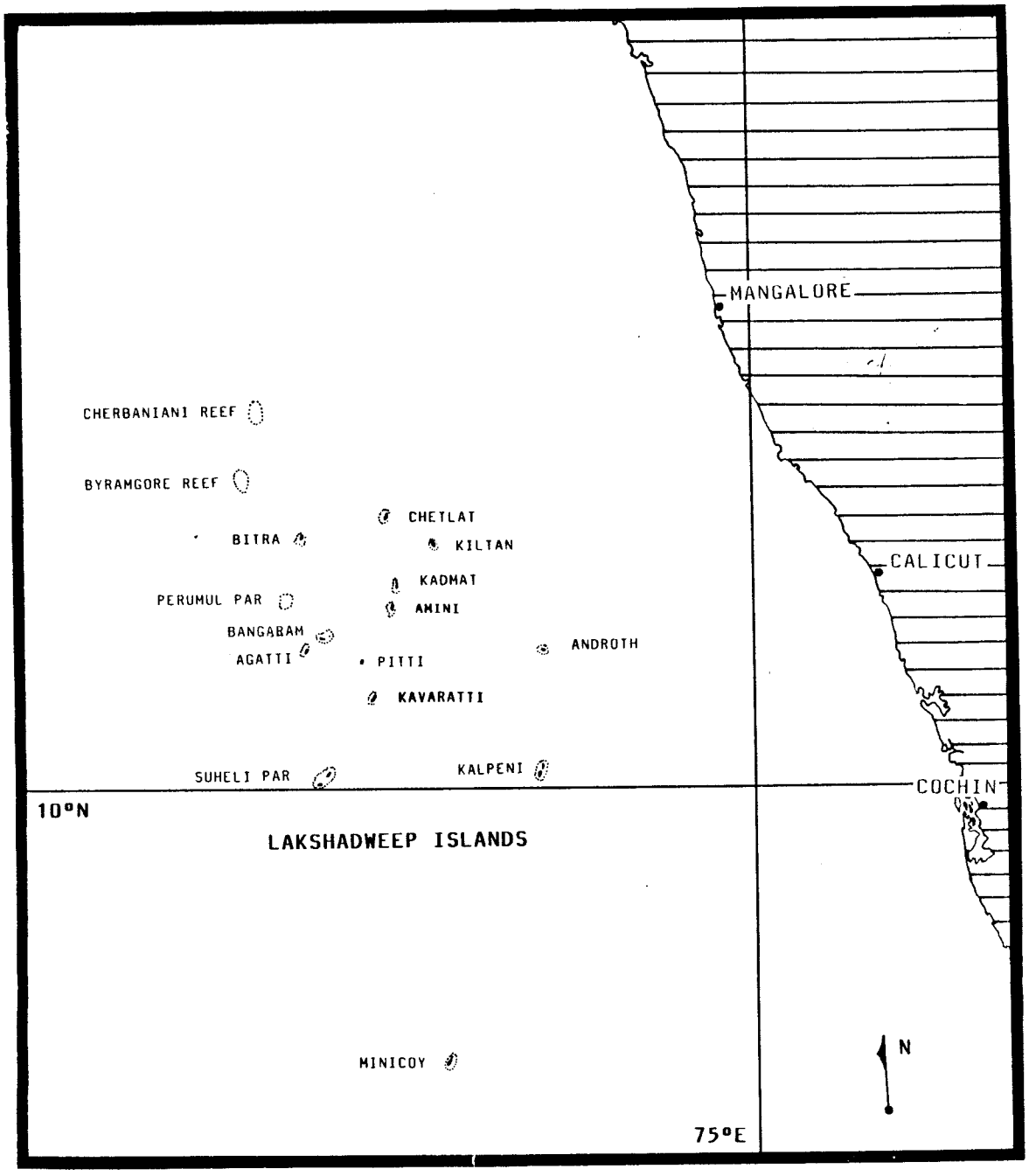
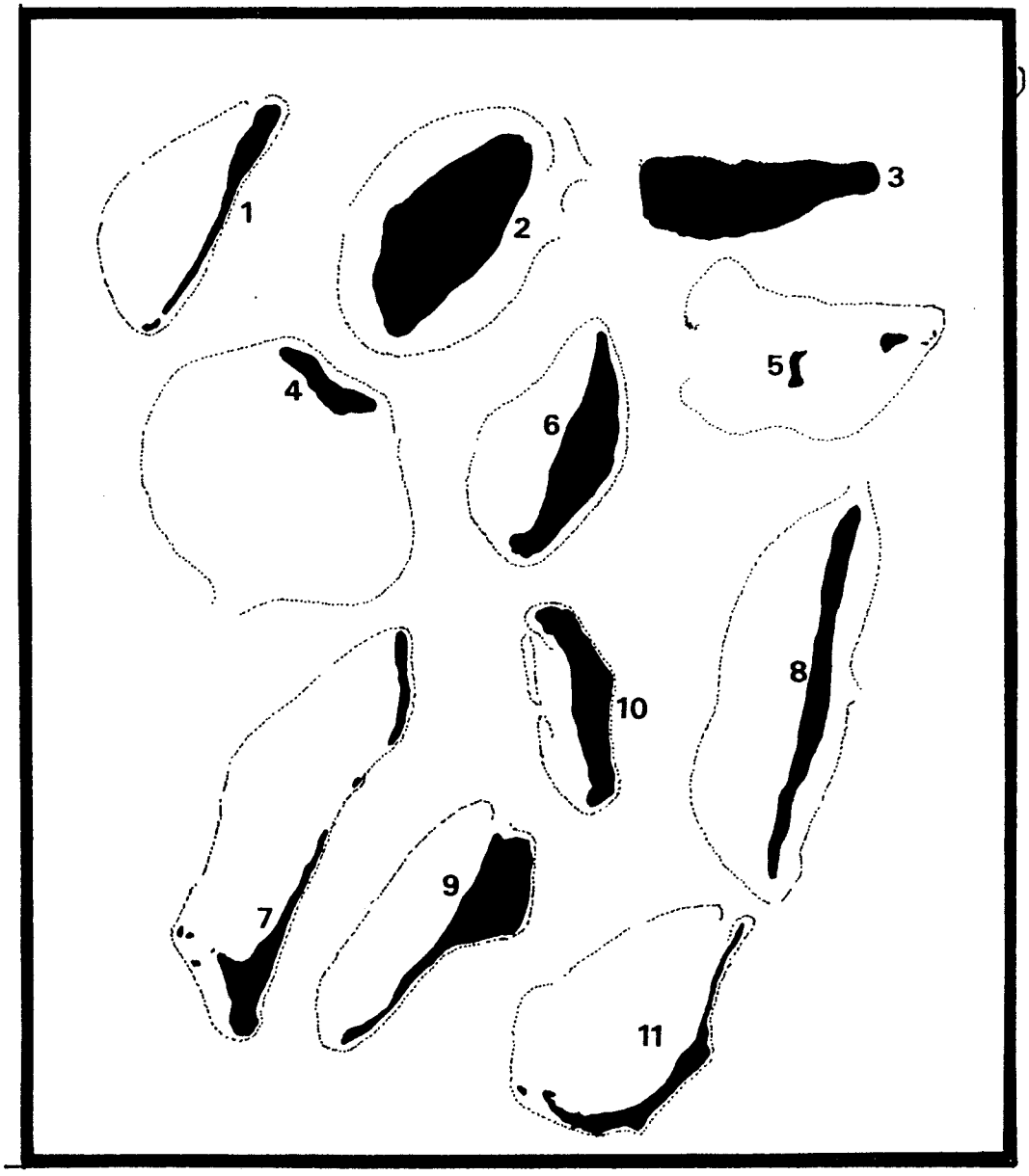


Figure 2. The Lakshadweep group of Islands;



1. AGATTI
2. AMINI
3. ANDROTH
4. BITRA
5. BANGARAM
6. CHETLAT
7. KALPENI
8. KADMAT
9. KAVARATTI
10. KILTAN
11. MINICOY

ISLAND

REEF CREST

Figure 3. General features of inhabited atolls of Lakshadweep.

Close to the leeward reef are present islets called Parali I, Parali II and Pitti (Photo 2). Suheli atoll comprises of two islands, Veliakara on the northern end of the leeward reef and Cheriyakara in the lagoon (Photo 3, 4). Bitra is the smallest island (0.1 Sq. km) while the greatest land area (4.8 Sq. km) is that of Androth (Photo 6). Minicoy is the longest island measuring approximately 10 km. Except Amini and Androth islands that are short and wide, all other islands are narrow and long. Apart from the small islets present on Bangaram atoll, the Southern ends of Agatti and Minicoy have islets called Kalpitti and Viringili respectively. On the Kalpeni atoll, Kalpeni and Cheriyam are major islands partially connected by the islet called Kodithali at low tides. Other islets, namely, Thilakkam, Pitti I and Pitti II on Kalpeni atoll are situated in the southern region.

The largest lagoons are those of Bitra, Bangaram and Minicoy. Except Amini and Androth, other atolls possess lagoons of a moderate expanse. Amini has the smallest lagoon (Photo 5). Androth does not have a lagoon as it is an island supported by a submerged reef (Photo 6). Maximum depths of 8 to 10 m exist in lagoons of Bitra, Minicoy and Suheli while average depths range between 2 to 5 m. Pitti Island is an unvegetated sand cay that supports nesting seabirds. Reef slope around Pitti decends gradually towards the north. Spur and groove formation are clearly seen between 2 and 10 m (Photo 7).

Zonation pattern on Lakshadweep's atolls is typical of oceanic atolls with seaward slopes dropping steeply to a depth of several hundred meters. Ten distinct zones were identified on the atolls. Zones on the windward side including the island are the sandy beach, lagoon floor, inner reef flat, reef crest, outer reef flat, reef slope and the reef front. On the leeward side the storm beach comprises of rubble, boulders and beach rock followed by a reef flat of 50 to 10 m wide and drops off to 60 to 100 m.

Features of individual zones differ between atolls. The sandy beaches have fine to coarse sand and beach rock at a few places. Occassionally, fine rubble was also observed. The lagoon floor comprised of features like seagrass forming dense beds on some atolls (Kalpeni, Kadmat and Kavaratti). Lagoons were generally sandy. Towards the windward side, the inner reef flat comprised of rubble toungues encrusted with coralline algae with patches of sand and massive coral generally forming micro-atolls. The reef crest was composed of huge boulders, intermittently exposed by low tides. The outer reef flat had depths ranging between 1 and 4 m, generally smooth and covered with coralline algae. Isolated patches of Acropora sp. and Pocillopora sp. were also observed. The reef slope has depths ranging between 3 and 10 m, and varies in width on each atoll (4 to 200 m). The spur and groove formation was evident on slopes with patches of sand between profuse coral growth. The reef slopes exhibit high fish species diversity.

On the leeward side, the storm beach is generally strewn with rubble of varying sizes. Coarse sand and beach rock were occassionally found. The upper edge of the reef flat has coral boulders encrusted with coralline algae while the lower edge is platform-like, the surge channels harbouring isolated patches of Acropora sp. and coralline algae. Beyond the reef flat (3 to 25 m) most atolls have steep reef slopes with a short spur and groove formation (Photo 7, 8) or a steep overhang.

2. The Andaman and Nicobar Islands: The present investigation covers details of the southern Andaman region. Fig. 4 and Fig. 5 show the location of south Andaman Islands and the areas surveyed respectively. These islands are emerged remnants of a teritiary mountain chain, and lie on a ridge which extends southward from Irrawady delta area of Burma, continuing the trend of the Arakan Yoma Range in the Bay of Bengal (6°45' to 13°41'N and 92° to 93°E).

There are about 500 islands, islets and rocky outcrops with a land area of 8293 sq.km. The important areas are north Andaman, middle Andaman with Ritchies Archipelago to the East, south Andaman, little Andaman, Baratong and Rutland Island. The larger islands are mountainous and covered by tropical rain forests. A stair-case model, topped with these forests, followed by mangrove fringes and coral reefs exhibit a unique situation (Photo 9).

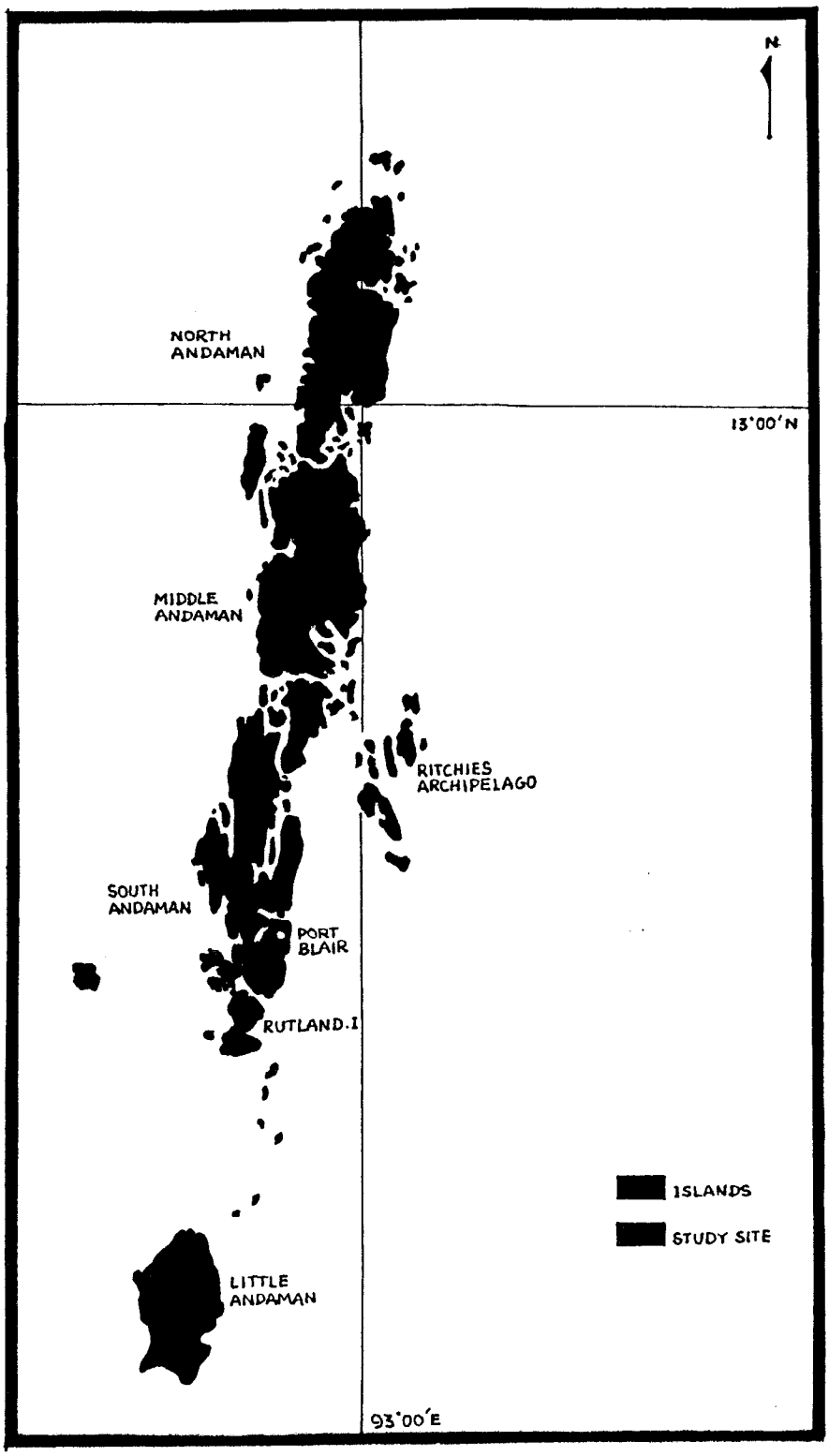
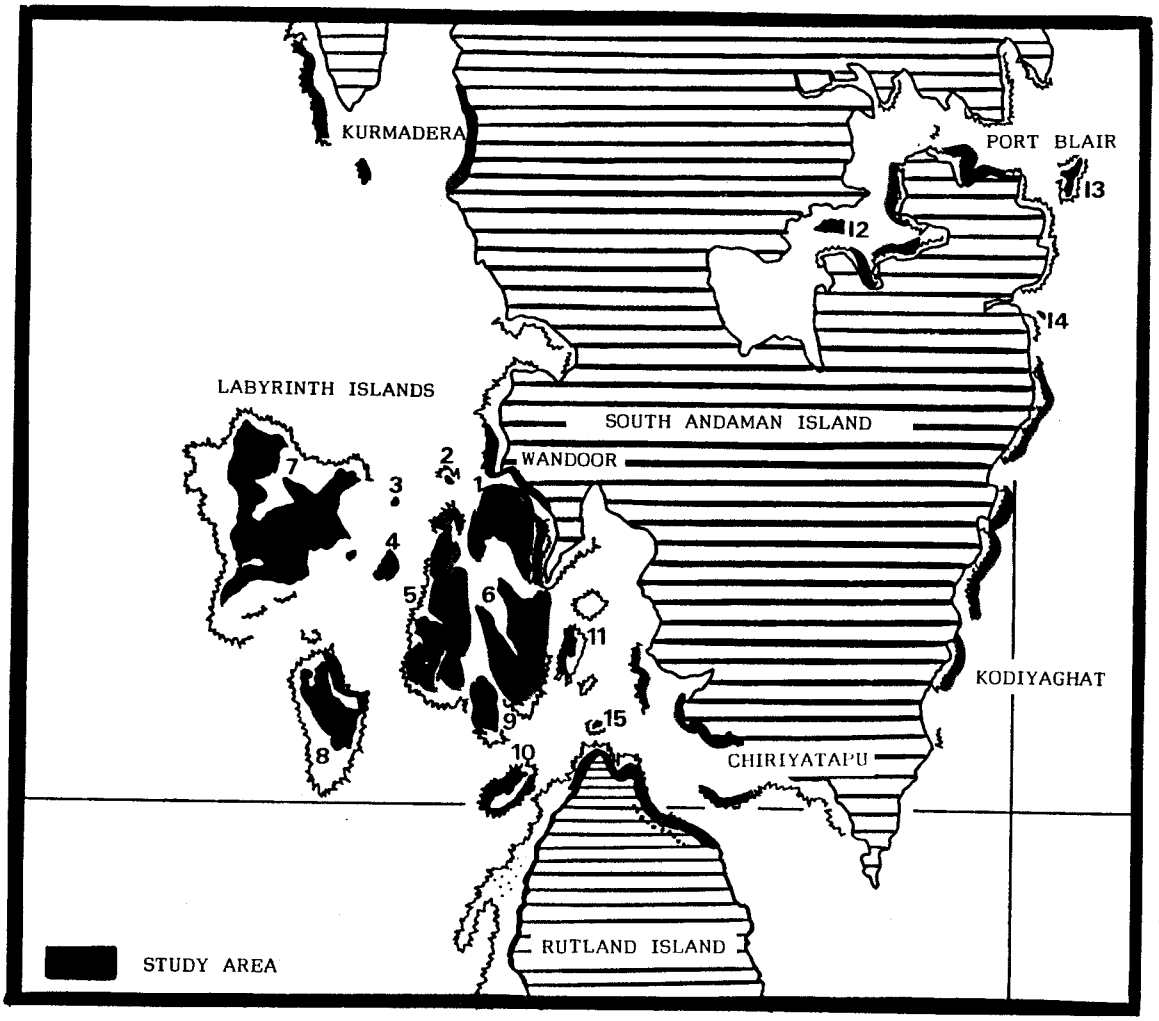


Figure 4. The Andaman Islands.



1. ALEXANDRA ISLAND
2. GRUB ISLAND
3. CHESTER ISLAND
4. SNOB ISLAND
5. RED SKIN ISLAND
6. HOBDAY ISLAND
7. TARAMUGIL ISLAND
8. BOAT ISLAND
9. MALAY ISLAND
10. JOLLY BOYS ISLAND
11. PLUTO ISLAND
12. VIPER ISLAND
13. ROSS ISLAND
14. SNAKE ISLAND
15. RIFFLE MAN ISLAND

Figure 5. The south Andaman Island and survey areas.

Most of the coral reefs are of the fringing type with varying widths (0 to 300 m) along the east and west coasts of Andamans with irregular depths due to uneven bottom topography. Channel reefs occur on the sheltered shore line where waters are calm due to lack of wind and wave action (Photo 9). Depths between reefs in the channel were nearly 40 m. Knolls rising from 20 m depth and Bay reefs with extensive sand zones are common. Reefs are mainly built by corals belonging to the genera Favia and Porites while Acropora and Pocillopora occur commonly. Extensive coral growth was observed around the islands of the Marine National Park of Wandoor and Kurmadera. Rock formations are prominent features on many parts of the coast line and are mainly sedimentary in origin made up of non-calcareous grey sand stone, lime stone and calcareous sand stone. They formed large tide pools which in turn support patchy coral growth, associated fauna and flora.

3. Coral reefs of Gulf of Mannar: About 20 coral islands with a land area of 625 ha and reefs are supported by a discontinuous submerged barrier reef that extends along the northern shore of Gulf of Mannar from Tuticorin to Rameswaram Island in the Bay of Bengal (8°48' to 9°14' N and 79°9' to 79°14'E). Four main groups, namely, Tuticorin, Vembar, Keleakkarai and Mandapam exist. The Keelakkarai group includes Anaipar, Valiamunai, Poovarasampatti, Appa, Talairi, Valai and Mulli Islands while the Mandapam group of islands that lie about 5 to 10 km off shore includes Hare, Manoli, Manoli Putti, Pulli, Pullivasal, Krusadai and Shingle Islands. Fig. 6 shows the representative areas covered under

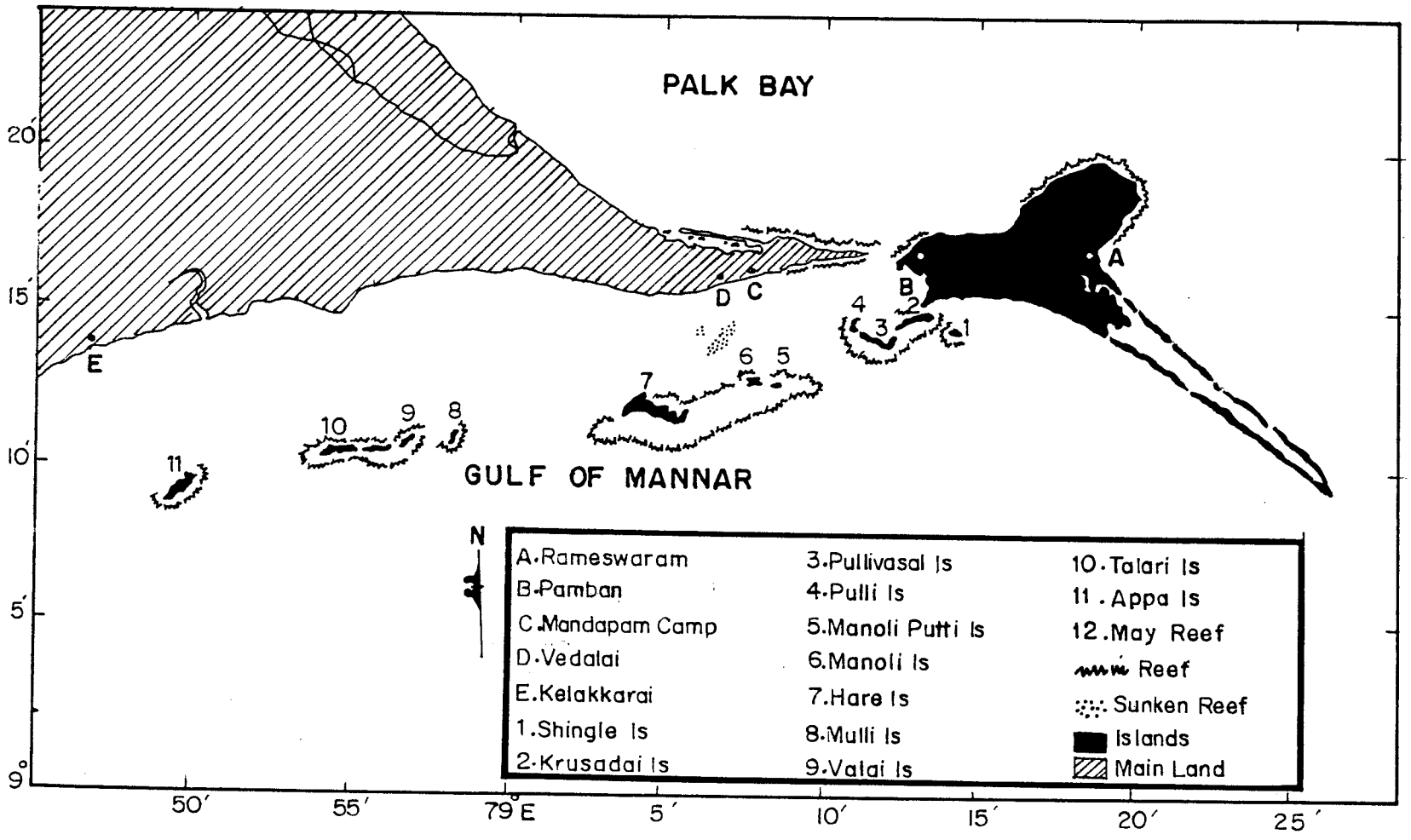


Figure 6. Fringing reefs of Gulf of Mannar Islands off Kelakkarai - Mandapam stretch.

this study. Except Shingle Island that composed of coral rubble and shell grit, all other islands are low sand structures. Mangroves and Pemphis acidula formed characteristic intertidal vegetation.

Coral reefs are mainly of the fringing type around the islands or patch reefs rising from the submerged limestone platform. Fringing reefs, 50 to 100 m away from the islands form reef flats inbetween with sediments of coral origin and seagrass beds. In many cases the reef surrounds the islands (Krusadai, Pullivasal, Hare, Manoli) while in others it is discontinuous or limited to patches. Coral growth on leeward flats has depths of about 1 m at low tides, while the seaward reef slopes drop to 4 to 5 m. In general, coral growth is relatively better in the Keelakkarai group when compared to the Mandapam group.

4. Coral reefs of Gulf of Kutch: The Gulf of Kutch is situated in north-west India, in the Arabian sea (22°15' to 23°40' N and 68°20' to 70°40' E) and has an area of 7500 sq.km. Maximum depths of the Gulf range between 40 and 60 m with an average depth of 20 m. It is wide at the seaward end (58 km) and tapers gradually eastwards, extending for nearly 170 km (Fig. 7). Of the 42 islands, Pirotan and Karumbhar are the main islands. An important feature of the Gulf is its tidal range of 4 to 7 m which generates fast currents upto 2.5 m per second. Coupled with effects of high tidal amplitude and large scale coral/sand mining and mangrove deforestation has resulted in pulling down large quantities of sediment onto the fringing reef area, destroying most of the corals.

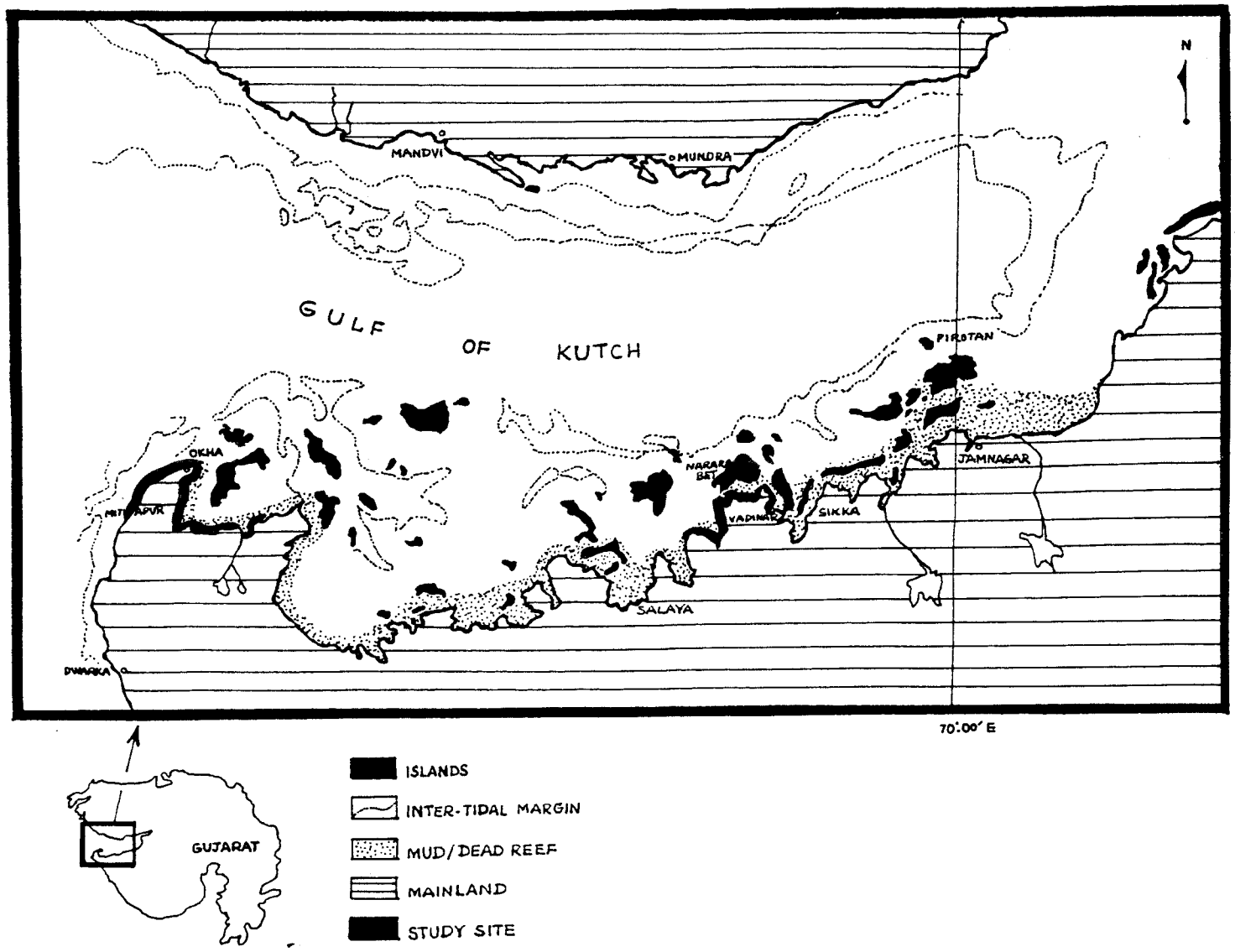


Figure 7. The Gulf of Kutch and survey areas.

Coral growth was poor when surveyed in 1992. Reefs appeared to be mainly of the fringing type with living corals confined to northern and western sides of the islands where currents were strongest. Wide expanses of sand stone also occurred, sand stone surfaces and tide pools were encrusted with different algae. Ramose corals belonging to the genera Acropora, Pocillopora, Stylophora and Seriatophora have not been found. Isolated patches of Porites spp. and Favia spp. have been observed coping up with adverse conditions. Turbidity was very high with visibility less than a metre. Sand dunes and sand banks were common features.

B. CHARACTERISATION OF SUB-HABITATS: The sub-habitats in the four geographical areas viz., coral atolls of Lakshadweep, South Andaman Islands, Gulf of Mannar and Gulf of Kutch are described in the following account.

1. Coral atolls of Lakshadweep: Seven sub-habitats have been classified on the coral atolls of Lakshadweep, namely live coral, massive coral, rubble, sand, seagrass and boulder zones. The reef slope is a major zone typical of oceanic coral atolls and was not included in the category of sub-habitats. Physical and biological features of each sub-habitat are described below:

a. Live coral: This zone comprised of dense, vast lagoonal patches of Acropora formosa normally growing on deep (2 to 5 m) sandy parts

of the lagoon that were relatively undisturbed. Dead fragments of the same species were found around the live patches in Kalpeni, Kavaratti and Minicoy due to human activity in removal of live coral for ornamental purposes.

b. Massive coral: This zone is generally situated on the inner reef flats at depths of 1.5 to 4 m. Porites spp. dominated the area and was found to grow on pre-existing dead coral base mainly forming micro-atolls. Isolated colonies of Acropora humilis and Psammocora contigus were also found in this region. The seaweed, Turbinaria sp. and coralline algae usually covered portions of dead massive coral. Discontinuous areas of massive coral growth had patches of sand in between.

c. Rubble: Vast expanses of most atolls were covered by rubble tongues extending shoreward, generally in shallow regions (50 cm to 1.5 m). South-western ends of the atolls and parts of the inner reef flats comprised of rubble in varying sizes. It composed of coral debris of 12 cm and below, at times mixed with sand. Profuse algal growth, ocypod and xanthid crabs were abundant.

d. Sand: Lagoons of all atolls had considerable areas of sand at depths between 0.5 to 5 m or more. Patchy growth of seagrasses, Cymodocea rotundata and Thalassia hemprichii occurred. Rubble mixed with sand in certain areas supported growth of algae. Fine to coarse grades of sand depending on current wave action existed.

e. Seagrass: These zones were conspicious in lagoons of all atolls except Bitra and Kiltan forming dense beds alongside the islands in calm zones (0.50 to 3 m depth). Six species of seagrasses, namely Cymodocea rotundata. C. serrulata, Halodula uninervis Halophyla ovata, Syringdium isoetifolium and Thalassia hemprichii occurred on the atolls, of which the latter dominated the beds. Seagrasses form raised tables due to efficient sediment trapping by the rhizomes in lagoon areas experiencing considerable wave action. The surrounding sand areas were unstable being continuously subject to transportation by currents (Photo 10).

f. Boulder: Dead coral boulders encrusted with coralline algae were found on the reef crest and on its sides. (ie., 1 to 2 m onto the inner reef flat and 1 to 4 m onto the outer reef flat) and the leeward reef flat. No coral growth among boulders was found on the windward side and a considerable area was exposed at low tides forming small tide pools that were inhabited by juvenile pomacentrids, wrasses, moray eels, sea cucumbers, star-fishes, ocypod and xanthid crabs. On the leeward side, calm areas between the boulders had isolated growth of Acropora humilis and Pocillopra sp. Large tide pools harboured adult and juvenile blenniids, gobiids, pomacentrids, serranids, wrasses and occassionally chaetodontids. Common seaweeds were Chaetomorpha sp., Hypnea valentiae, Laurencia sp. and Padina boergeseni.

g. Reef slope: This zone is typical of most coral atolls of Lakshadweep and extends between depths of 4 to 10 m beyond which is the reef front that steeps abruptly. Width of the reef slope is highly variable among areas on each atoll and between atolls. Generally the width ranges approximately between 8 to 150 m, following the outer reef flat. Most commonly it is about 40 m. This zone exhibits high diversity in fauna, flora and sub-habitat types. Massive and branching corals grew profusely in this region, but heavily silted dead zones were observed on atolls with increased human interference (Kavaratti and Minicoy). Patches of sand occurred between protected areas of massive coral growth and between the spur and groove formation (Photo 7, 8) that was conspicious on most slopes.

2. The south Andaman Islands: Eight sub-habitats were classified in the south Andaman Islands, namely, dead coral, live coral, mangrove root, rock, rubble, sand/mud, seagrass and soft coral zones. Physical and biological features of each sub-habitat are described below:

a. Dead Coral: This zone occurrs amongst reef flats, bay, channel and subtidal reefs. The zone is comprised of massive corals and to a lesser extent by branching corals, all of which were encrusted with coralline algae or overlaid with silt. Vast expanses of reef flats were formed by dead coral at Chiriyatapu, Kurmadera, Pongibalu, Port Blair and Rutland Island. This zone sheltered abundant

invertebrate fauna of which Tridacna sp. was conspicious. Chaetodontids, labrids, pomacentrids, scarids, serranids etc were observed on the sub-habitat (Photo 11).

b. Live coral: This zone comprises of both massive and branching corals (Porites spp. and Acropora spp. respectively) that form fringing reefs around many islands. Coral growth was profuse on seaward edges of the fringe and in channel reefs. The branching types were abundant on seaward edges near Boat, Jolly boys, Kurmadera, Red skin, Ross, Rutland and Taramugli Islands with Acropora, Goniopora, Montipora, Pocillopora, Stylophora and Seriatopora as the commonest genera. The massive coral genera were Favia, Favites, Platygyra, Symphyllia, Goniastrea, Diploastrea and Porites, a majority of them being builders of channel reefs between Alexandra, Hobday, Malay, Pluto, Red skin and Riffle Man Islands (Photo 12). Fish fauna was the most diverse in this region, and particularly dominant were Anthias squamipinnis, chaetodontids and pomacentrids.

c. Mangrove root: This is an intertidal zone formed by mangrove roots along bays, creeks and channels of small islands around Wandoor and other coastal areas around south Andamans. Important species occurring in the area were Aegiceras corniculatum, Avicennia marina, Barringtonia racemosa, Bruguiera gymnorhiza, B. parviflora, Excoecaria agallocha, Nypa fruiticans, Rhizophora muscronata, R.

apiculata, Sonneratia caseolaris and S. alba and were well preserved. The sub-habitat was generally 3 to 5 m wide, depending on the mangrove growth and harboured a variety of invertebrates and juvenile fishes. Water depth ranged between 0 to 50 cm around the roots at low tides and 2 to 4 m on the adjacent, narrow reef flat with a visibility of 4 to 6 m. Porites spp. was an important builder with a few patches of Acropora spp.

The proximity of live coral growth and mangroove roots was at times just a metre (Photo 13) where sediments were generally absent (between Alexandra, Hobbay, Malay, and Red skin Islands) while at Rutland Island the reef and mangrove root zone were separated by muddy zones of 500 m wide. The coastal mangrove root zone differed from the channel root zone in the lack of living coral at proximity but replaced by muddy or sandy zones on limestone substratum. Seagrass - mangrove root association was not found. Ocypnd and xanthid crabs that are important food items for fishes take shelter among mangrove roots. Important algae forming food for herbivorus fishes were Enteromorpha, Chaetomorpha, Cladophora, Ectocarpus, Ulva, Padina etc. Juveniles of labrids, lethrinids, mugilids, scarids, serranids and few adult chaetodontids were observed.

d. Rock: Rocks of sedimentary origin made up of non-calcareous grey sand stone, lime stone and calcareous sand stone comprised the rocky zone. They were found on the seaward coasts of the south Andaman,

Rutland Islands and in bays around Port Blair. Large tide pools of nearly 1 m deep were often formed by rocks which supported miniature coral reef ecosystems. Acropora spp. anemones, coralline algae, Porites spp, Tridacna spp. and fishes like chaetodontids, pomacentrids and wrasses were observed.

e. Rubble: These zones occurred patchily along unprotected shores and in bays along with sand. Rubble comprises of dead coral fragments, molluscan shells and pieces of rock. A majority of the area was found on intertidal regions at depths below 1 m. Except for molluscs like Arca, Drupa, Thais, Tridacna and Turbo, other fauna and flora were less diverse. Fishes were not recorded from the region.

f. Sand/mud: This zone was usually found on unprotected shores of south Andaman and Rutland Islands. The numerous bays along the shore line between reef edges and the coasts comprised of sand or mud or mixtures of both in varying proportions. The zone was devoid of rich fauna and flora except invertebrate burrowing forms and juvenile fish.

g. Seagrass: These zones occurred on sandy or muddy areas in protected bays and were sparse. A few patches have been observed between Pongibalu and Riffle Man Island at depths between 1 to 3 m. Acanthurids, Scarids and juveniles of fishes were abundant.

h. Soft corals: These zones occurred in association with massive corals and sandy bottoms forming dense colonies in shallow waters of 1 to 3 m depth. Except Lobophytum sp., Sarcophyton sp. and Sinularia sp., other soft corals could not be identified. Chaetodontids, pomacentrids and serranids (Anthias squamipinnis) were notable fish fauna.

3. Gulf of Mannar: Ten sub-habitats were classified around the islands in Gulf of Mannar, namely, dead coral, Enhales acorodies, live coral, mangrove root, massive coral, Pemphis acidula, rubble, sand, Sargassum sp. and seagrass zones. Physical and biological features are described below:

a. Dead coral: This zone comprised of dead massive coral and submerged coral platforms (reef flats). In most cases it was continuous and adhered to islands with widths ranging between 1 and 10 m. Such areas were extensive around Hare Island. Encrusting algae and Sargassum sp. in patches grow in the area. Corals of the genera Porites spp. appear to be main builders of the zone. At many places sand or shingle replaced dead coral zones. Number of crevices provided shelter for fishes like labrids, moray eels and serranids.

b. Enhales acoroides: The seagrass Enhales acoroides formed distinct sub-habitat zones near Krusadai, Manoli and Pullivasal Islands.

These dense seagrass beds had areas between 6 to 20 m. Depths in the region were normally 1 m at low tides with a sandy base and leaf blades reaching the water surface. Fish fauna was however low with a few specimens of lethrnids and serranids in their sub-adult stages.

c. Live coral: This zone was patchy and comprised of massive and branching corals growing on the outer edges of the reef (southeast and northwest) at depths of 2 to 5 m. Important species among the massive corals were Porites solida and P. somaliensis that were recorded in relatively calmer waters (Appa, Hare, Krusadai and Manoli Islands), while foliacious branching types were recorded in areas with mild currents and good water circulation. Commonly occurring species were Acropora formosa, A. hyacinthus, A. surculosa and Montipora foliosa. Small crowded patches of Acropora colonies were observed on the leeward side (northwest) while they were rather spread out on the windward side (southeast). A variety of fish fauna typical of coral reefs (balistids, chaetodontids, labrids, pomacentrids, scarids and serranids) were observed around Acropora colonies. In general the Keelakkaria group of islands potrayed better reef conditions and coral reef fish fauna when compared to the Mandapam group.

d. Mangrove root: Mangrove roots formed an intertidal sub-habitat on the leeward sides of most islands (northwest). The base was

generally muddy or sandy with occassional patches of shingle (shell grit). Depths on this zone were about a meter (Photo 14). The important species of mangroves were predatory fishes like lethrinids, lutjanids, serranids, juveniles of coral reef fishes and commercially important fishes like mullets and milkfish which occurred in moderate numbers.

e. Massive coral: This zone was recorded on all islands and comprised exclusively of live Porites spp. patches. Common species were Porites solida and P. somaliensis which were important reef builders and supported colonies of live Acropora spp. Depending on the extent of branching coral growth a possible overlap between this sub-habitat and live coral zones could occur at a few places. Fish fauna was similar to that of live coral patches.

f. Pemphis acidula: This intertidal zone was formed by the coastal shrub, Pemphis acidula (Photo 15). The shrub has hard wood and rigid branches and grew partially on dead coral substratum and on the beach, on the leeward sides of few islands (Hare, Krusadai, Talari and Valai Islands). Sub-habitat functions were similar to the mangrove roots in providing shelter to different fauna and flora. Juveniles of fishes were observed in abundance.

g. Rubble: This sub-habitat occurred in the intertidal zone both on the windward and leeward sides of the islands. It comprised of a

mixture of coral rubble and shell grit, the proportion varying with the region. Higher amount of shell grit was found on shingle Island and on windward sides of Hare Island, while coral rubble was observed in low quantities around most islands. Except blennids and gobiids, other fish fauna were not recorded from the area.

h. Sand: Sand or muddy zones were common sub-habitats around all islands specially in protected lagoons between islands and outer reef edges. The area was often turbid with depths between 1 and 2 m. Sand also formed an important base for Enhales acoroides and Thalassia sp. that formed distinct sub-habitats. Fish fauna observed in the area were mullets, milk fish and lethrinids.

i. Sargassum: Vast Sargassum sp. beds growing on dead coral substratum formed distinct zones at Appa, Hare, Manoli and Pullivasal Islands. This sub-habitat is found on calm leeward sides of the islands, at depths between 0.5 to 2 m. Fish fauna was absent from this region.

j. Seagrass: This zone comprised of the seagrass, Thalassia sp. in protected zones around the islands. The typical mangrove - seagrass association was observed on the leeward side of Manoli island (Photo 14). Vast areas of seagrass were found at the Keelakkarai group of islands and were less dense on the Mandapam group. The sub-habitat formed ideal nursery grounds for juvenile fishes and invertebrates that form food items for fish.

4. Gulf of Kutch: Five sub-habitats have been classified from the reef areas off the coast of Gujarat from Jamnagar to Okha, namely dead coral, massive coral, mud/mangroves, sand and Sargassum sp. zones. Physical and biological features are described below:

a. Dead Coral: This zone comprised of dead massive corals normally away from the coast line on the outer edges of the reef, covered heavily with silt and algae. At few places this zone is platform-like and merged with sand stone or beach rock at depths between 0.50 to 1.50 m (Photo 16). Striations similar to the 'spur and groove' were found on sand stone reef platforms covered with algae. Except few serranids, typical coral reef fishes were absent.

b. Massive coral: This zone was extremely patchy and comprised of isolated colonies of Favia spp. and Porites spp. on reef edges and shallow areas adjescent to the reef edge but away from the coast line. Siltation and growth of filamentous algae was often found to choke corals during receeding tides (Photo 17). Sargassum sp. was also found among massive corals. Large schools of juvenile Plotosus lineatus and solitary sub-adult serranids were observed.

c. Mud/mangroves: Vast areas along the coast line were muddy with traces of immense mangrove deforestation now leaving behind only stunted mangrove shrubs (Photo 18). Remnants of massive coral mixed up with mud and in certain places, embedded intact on dry coastal land was observed (Photo 19). Only mudskippers were conspicuous fish fauna.

d. Sand: Majority of the areas in the Gulf were sandy or mud mixed with sand. Large expanses were often exposed during low tides due to the high tidal amplitude. Certain deeper regions formed tide pools at low tides. Conspicuous fish fauna were mudskippers.

e. Sargassum: The brown sea weed, Sargassum sp. formed distinct patchy zones on dead coral substratum in shallow depths of less than a metre. Other sea weeds like Caulerpa sp., Padina sp. and Ulva sp. were also present in low quantities growing on sand stone. Juvenlies of Abudefduf sexfasciatus and Therapon sp. were observed.

DISCUSSION

From the scientific point of view, the atolls of Lakshadweep have hitherto received scanty attention. Inspite of recent works related to zonation from the region (Mallik, 1985; Pillai, 1986 and Victor et al., 1989) large gaps still remain. Andaman and Nicobar Islands and the Chagos Archipelago remain largely unknown (Stoddart, 1973). Well marked distinctions on windward and leeward reefs exist on Addu atoll, Maldives (Davies, et al., 1971; Stoddart, 1973), and similar physiographic zones were found on atolls of Lakshadweep. Reefs of Andamans, Gulf of Mannar and Gulf of Kutch have been studied well with regard to coral species distribution but no accounts on physiographic zonation is available.

In the present investigation an attempt is made to describe physiographic zonation on atolls of Lakshadweep with modifications to the earlier work (Vijay Anand and Varghese, 1992b). Only few investigators (Namboodri and Sivadas, 1979) have reported various physiographic zones often on limited areas. Cocos - Keeling, the Chagos and the Maldives are broadly similiar to reefs of the Addu atoll (Davies et al., 1971) and correspond with that of atolls of Lakshadweep and is probably due to the fact that Maldives and Lakshadweep fall on the same ridge (Laccadive - Chagos Ridge) and monsoon belt (Southwest monsoon). Symmetry in the atoll shape, rubble toungues originating from the boulder zone forming windrows (Photo 20), and typical storm beaches on the northern, southern and leeward regions are suggestive of the northeast and southwest monsoon effects. Rubble tongues in the Maldives extend about 50 m inshore indicating periodic storm formation (Davies, 1971) while storm rubble is found on all sides of atolls in the northern Marshalls (Mac Neil, 1972).

The ten physiographic zones identified are common to all atolls except for minor regional variations on few atolls. The sub-habitats described in this chapter are details contained in each physiographic zone and are usually termed based on conspicious characters (animals, plants and non-living structures). For example, the Acropora zone also called as live coral or branching coral zones and extensive areas dominated by Porites sp., called the massive coral zones. The algal ridge which is formed essentially of Porolithon spp. is a typical feature

of oceanic reefs but has not been reported from Lakshadweep (Gardiner, 1903). They are known to be less prominent in the Indian Ocean (Stoddart 1973). A structure on the outer reef flat resembles the algal ridge described on Addu atoll but the algal components of the region need to be studied to confirm identify of this zone.

The reef slope generally extends to about 40 m from the reef flat but at widest places it is about 150 m including the spur and groove zone at 10 m depth. Stoddart (1973) did not observe the spur and groove system beyond 25 m depth but it commonly occurred within 12 m depth with widths of 100-300 m. Proximity of the zone occurred around the only two lagoonless islands, Androth and Pitti in Lakshadweep. A break on the slope at approximately 25 m formed a distinct edge with a decrease in corals and other species (Davies et al., 1971); this zone has been termed reef front in the present investigation.

Lagoons in general were shallow on Lakshadweep atolls and zonation within the lagoon was different from that described on Addu atoll (Davies et al., 1971,Stoddart 1973), probably due to shallow depths, while lagoon zones described in Tulear and Madagascar (Stoddart 1973) shared similarities with Lakshadweep. Knolls have been described by Gardiner (1903) and their presence was reported to be few on Addu atoll. These are presumably structures that rise 20 m above their base (Davies et al., 1971).Such structures do not occur on atolls of Lakshadweep as lagoons are shallow. By way of description it appears that micro-atolls that are

common on the inner reef flat (inner lagoon edge) have been mistaken to be knolls while the deepest lagoons of Lakshadweep (Bitra, Minicoy and Suheli) show the presence of only patch reefs.

Leeward sides of the atolls have typical storm beaches with steep beach face slopes, berms and uplifted reef plates. The ages of storm beaches were studied by Siddique (1980). Beaches are sandy on the leeward side on southern regions of Agatti Amini and Bitra while the leeward reef flat is wide, creating a lagoon (10 to 60 m wide), thus forming a barrier against storm debris transportation. Storm beaches rarely occur on the wind-ward side except on the northern region of Minicoy. The tip is a narrow storm beach strip which probably will get cut off leaving a small vegetated islet. Southern regions of Agatti (islet - Kalpitti), Kalpeni (islets - Pittis and Tilakam) and Minicoy (islet - Viringili) have small vegetated islets generally made of storm debris. Kalpeni has a storm bank that is exposed on low spring tides. A narrow constriction (25 m) called the 'chicken neck area' in the southern region of Kavaratti has a storm beach and is likely to get cut off due to erosion (Photo 20). It is possible that southern islets are resultant of southwest and northeast monsoons that deposit sediment and storm material from both sides. Kodithali, the islet between Cheriyam and Kalpeni atoll (Fig 3) is formed due to accretion and is composed of coral sand and less of storm debris.

Though sediment transportation in lagoons and along side the islands is away from the present investigation plan, personal observation suggests that sediment is highly mobile within the lagoon moving to and fro with no gross sediment loss occuring due to monsoon winds that effect the atolls in opposite directions. Sediment gradation with distance is conspicious with large boulders and cobbles in areas of intense wave lashing. Finer sediments occur away from windward reefs indicating dwindling water transportation capacity.

Investigations on zonation patterns do not exist. However, descriptions of reef types and coral species composition have been given by few workers in Lakshadweep (Gardiner, 1903; Mallik, 1979; 1985 b; Namboodri and Sivadas, 1979; Pillai, 1983 a, 1986; James 1989; Victor et al., 1989; Vijay Anand and Varghese 1990,1992b), Andamans (Kloss, 1902; Reddiah, 1977; Mahadevan and Easterson, 1983; Pillai, 1983 b), Gulf of Mannar (Reddiah, 1970; Rajendran and David, 1972; Mergner and Scheer, 1974; Silas et al., 1977) and Gulf of Kutch (NIO, 1978; Pillai et al., 1980; Patel, 1985).

Greater diversity in sub-habitats (10 nos) in Gulf of Mannar is attributed to the submerged nature of basal reef platform, mangroves and the seagrass-Enhales acoroides while in Andamans it is due to rocky and mangrove areas. Least number of sub-habitats recorded from the Gulf of Kutch is due to extensive environmental degration.

Live coral zones of Andamans and Gulf of Mannar were similar in structure and composition; mainly built by a combination of Porites and Acropora spp. forming fringes or patch reefs. Normally Porites assemblage forms steep vertical reef fronts in channels and protected areas making up a frame work over which delicate forms grow (Stoddart, 1973). Similar assemblages were observed along protected channels in Andamans by Reddiah (1977) and Pillai (1983 b) and in the present investigation in Andamans and leeward sides of Gulf of Mannar reefs (present investigation). Mergner and Scheer (1974) observed micro-atolls formed by Porites solida and adjacent Acropora colonies at Manauli Island in Gulf of Mannar. Live coral zones on the atolls of Lakshadweep showed clear demarkation within the lagoons with Acropora formosa forming patch reefs and Porites spp. forming micro-atolls. The mixed coral zone was found on reef slopes and occassionally in deeper parts of the lagoon (Bitra, Minicoy and Suheli) and were in accordance with live coral zones on Addu atoll (Stoddart, 1973). Patchy corals in the Gulf of Kutch are diminishing (Patel, 1985) while branching corals are presumed to occur in earlier years (Pillai et al., 1980). The Observations in the present study picture a fully dead environment with few massive coral species thriving in adverse conditions in the Gulf of Kutch.

Rubble zones occurred in all geographic areas except in the Gulf of Kutch. Most extensive rubble zones are those on Lakshadweep atolls, a prominent feature on most atolls (Davies et al., 1971; Mac Neil, 1972; Stoddart, 1973) while in Andamans limited rubble zones occurred in

protected areas like bays and between rocky outcrops. Pillai (1983 b) referred to rubble zones as 'coral shingle'. As flat expanses on fringing reefs are limited, depositional features like rubble did not contribute to forming significant sub-habitats in the Andamans and Gulf of Mannar. Rubble probably existed in the Gulf of Kutch but is not traceable due to intense sedimentation.

Most extensive sand zones occur in Lakshadweep and is mainly composed of calcium carbonate. Mallik (1979) described other components of coral sand originating from coralline algae, foraminiferan, ostracod and molluscan remains. Sand from areas in Andamans, Gulf of Mannar and Gulf of Kutch differed in composition from that in Lakshadweep with terrestrial mud as a major component. These zones form base material for mangroves, seagrass and rubble.

Seagrass beds cover large areas in water of appropriate depth on mud or sand flats, usually below low tide levels in coral reef ecosystems (Fosberg, 1973). Two species of seagrasses have been reported from Maldives, and little is known about marine angiosperms on Indian ocean reefs (Stoddart, 1972, 1973). Six species of seagrasses occur on Lakshadweep atolls, of which Thalassia hemprichii is dominant forming extensive beds along side the islands and often get exposed at low-water spring tides. Gopinathan and Panigrahy (1983) did not mention about seagrasses in Andamans while Cymodocea. sp. and Thalassia sp. were reported to cover considerable areas on the bottom of inshore waters (Pillai, 1983 b). The present investigation revealed only patchy seagrass

beds probably due to absence of protected sand/mud flats on fringing reefs and is further substantiated by low occurrence of herbivorous fishes. Seagrasses constituted 15.75% of the reef flora studied from Gulf of Mannar and Palk Bay (Rao, 1972); Thalassia hemprichii grew near the sandy-muddy eulittoral (Mergner and Scheer, 1974). In the Gulf of Mannar seagrass formed extensive beds between the mainland coast and the leeward sides of the islands with a notable proximity between seagrass beds and mangroove root zones. Such an association was reported by Thayer et al. (1987) who studied fish fauna between the two habitats. Enhales acoroides was not reported by Rao (1972) among the four species of seagrasses described. This seagrass formed pure, dense stands in the Gulf of Mannar. Chuang (1977) recorded 15 individuals of E. acoroides per sq. m in regions around Singapore. Enhales sp. is an important component on seagrass meadows (Fosberg, 1976). Seagrasses were not found in the Gulf of Kutch region.

Sargassum reef slopes in Singapore were described by Chuang (1977) while it formed 13.10% of algae studied in Gulf of Mannar and Palk Bay (Rao, 1972) and occurred mainly on shore-ward parts of the reef. Sargassum sp. was reported to grow on dead reef flats around Manauli Island (Mergner and Scheer, 1974) while in the present investigation Sargassum zones were recorded on dead coral platforms, windward lagoon areas in the Gulf of Mannar and on dead coral zones in the Gulf of Kutch.

Pemphis acidula zones are common in Indo-Pacific region and grow well in salt spray zones with roots covered with seawater at high tides

(Fosberg, 1976). Such zones formed intertidal sub-habitats in the Gulf of Mannar but not in Lakshadweep where they grow away from water. This scrub zone was not observed in other regions.

Mangroves are not present in Lakshadweep (Stoddart, 1972, 1973; James et al., 1989). Forked, aerial prop roots covered vast areas in the Andamans forming important sub-habitats due to mangrove zone abundance. According to the mangroove classification by Gopinathan and Rajagopalan (1983), those occurring along creeks form significant fish habitats as compared to coastal mangroves. Leeward sides of few islands harbour mangroves in Gulf of Mannar. Most mangrove areas in the Gulf of Kutch were destroyed. Pillai et al, (1980) observed the most luxuriant growth around Pirotan Island.

Boulder zones surround all atolls of Lakshadweep with widest portions (6 to 10 m) occurring on the northern and southern parts of atolls. Suth zones were absent from other regions. Similar zones were reported by Stoddart (1973) on Addu atoll, Mauritius, Seychelles, Tulear and Madagascar.

Reefs of Gulf of Mannar are fairly well described while those of Gulf of Kutch are poorly known inspite of few studies in the region. Long term integrated studies on oceanic reef systems (Lakshadweep and Andamans) to describe reef features do not exist. The present account on detailed physiographic description of Lakshadweep atolls provides base data for

comparative studies on atolls in other regions and further supplementation of information. Andaman Islands need to be studied more due to wide variations within the system.

CHAPTER II

DISTRIBUTION OF FISHES IN THE CORAL REEF ECOSYSTEMS OF INDIA

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INTRODUCTION

A large number of species of fishes is known from different coral reef ecosystems of India. Unlike a majority of marine fishes, the fishes inhabiting coral reef regions are very distinct in their appearance, particularly with respect to the colour pattern. Besides, certain distinct assemblages of fish species are known to be associated with particular coral reef sub-habitats (de Boer; 1978; Luckhurst, 1978a; Bell and Galzin, 1984; Bouchon-Navaro et al., 1985; Roberts and Ormond, 1987; Sale, 1991). A comprehensive list of species of fishes inhabiting different coral reef ecosystems of India is not available though several species were described by Day (1878), Herre (1938), Jones and Kumaran (1980), Talwar and Kacker (1984) and others. However, the surveys made by various workers have yielded information on the fishes of particular coral reef ecosystems. It is hence believed that a list of fish species associated with the four major coral reef environments (Lakshadweep Islands, Andaman Islands, Gulf of Mannar and Gulf of Kutch, region) will be useful for those interested in these fishes. While attempting this, it

has been considered that a list of species known to be more abundant in coral reef environments, and their distribution in the four regions mentioned above will be adequate and of immense use not only for further research in taxonomy, biology, ecology etc. but also in the trade of ornamental fish. Thus, a total of 421 species belonging to 26 families have been listed and their distribution in the four regions given in this account, taking into consideration the present collections as well as earlier reports.

Of the 421 species, 12 from Lakshadweep, 2 from Andamans, and 16 form the Gulf of Mannar region are new distributional records for the respective regions. However, since all these species have been described from other regions in the country, it has not been considered necessary to give descriptions of these species. The present work also brought to light 9 species which have so far not been reported from the entire Indian EEZ. Descriptions of only these nine species are given here, since a detailed taxonomic study of all the species collected from different regions is not within the purview of the present work.

MATERIAL AND METHODS

Collections have been made from the four coral reef regions, viz., Lakshadweep, Andaman Islands, Gulf of Mannar and Gulf of Kutch using gill nets, seine nets, drive-in-nets, encircling nets and traps. Collections in the Directorate of Fisheries, Kavaratti, Lakshadweep; Central Agricultural Research Institute, Port Blair, Andaman Islands; Regional Centre of Central Marine Fisheries Research Institute, Mandapam Camp,

Tamil Nadu (Gulf of Mannar region) and the Aquatic Science Research Institute, Okha, Gujarat (Gulf of Kutch region) have also been examined.

For the purpose of identification, the publications of Day (1878), Weber and de Beaufort (1913, 1916, 1922, 1929, 1931, 1936) de Beaufort (1940), de Beaufort and Chapman (1951), de Beaufort and Briggs (1962), Fischer and Whitehead (1974), Burgess (1978), Jones and Kumaran (1980), Fischer and Bianchi (1984) and Smith and Heemstra (1986) have been consulted.

Details of colour pattern have been noted and/or photographed immediately after capture. The specimens have been preserved in 10% formalin and in case of larger individuals, the preservative was injected into the abdominal cavity and different parts of the body. For the collection of morphometric and meristic data, the methodology of Hubbs and Lagler (1947) has been followed. Scales and the fin ray counts have been made on the left side using a binocular microscope. The lateral line scale count (Ll.) refers to the pored scales; when the lateral line is incomplete, the unpored scales in the horizontal row from behind the last pored scale in the lateral line to caudal base are also counted. In such cases, the data are presented as Ll. 18 + 8, meaning 18 pored scales and 8 unpored scales in the same row. Length measurements have been made along the median longitudunal axis. The body proportions are expressed as percent of standard length; the mean values are given in parantheses following the range for each character.

The details of the measurements taken are : Body depth - maximum vertical height at origin of dorsal fin; head length - tip of snout to posterior margin of opercle; eye diameter - maximum horizontal distance between front and hind margins of eye; interorbital distance - distance between the orbits; head depth - maximum vertical height at the hind margin of eye; predorsal distance - from tip of the snout to origin of spinous dorsal fin; spinous dorsal, soft dorsal and anal height - maximum vertical heights of the fins; spinous dorsal base - distance between first and last dorsal spines; soft dorsal base - distance between first and last fin rays; anal length - maximum length of anal fin; anal base - distance between origin of first anal spine to last anal fin ray; pectoral length - distance from base of the fin to its tip; pelvic length - distance from base of the fin to its tip; depth of caudal peduncle - height at the centre.

The list of species of the 26 families (Muraenidae, Holocentridae, Serranidae, Plesiopidae, Apogonidae, Malacanthidae, Lutjanidae, Caesionidae, Haemulidae, Lethrinidae, Mullidae, Chaetodontidae, Pomacanthidae, Pomacentridae, Labridae, Scaridae, Cirrhitidae, Mugiloididae, Siganidae, Zanclidae, Acanthuridae, Scorpaenidae, Balistidae, Monacanthidae, Ostraciidae, Tetraodontidae) along with the distribution of each one of them in the four coral reef regions is given in Table 1. While preparing this list care has been taken to avoid inclusion of invalid or incorrect names by consulting the most recent taxonomic literature.

Section A in this chapter deals with new distributional records and section B with the distribution of coral reef fishes on the four coral reef ecosystems.

A. NEW DISTRIBUTIONAL RECORDS

FAMILY : HOLOCENTRIDAE

1. NEONIPHON OPERCULARIS (VALENCIENNES, 1831)

(Blackfin squirrelfish)

(Photo. 21)

Material examined: One specimen, 280 mm SL, taken by hook-and line from Kavaratti atoll.

DESCRIPTION

D. XI, 13; P. 14; V. 7; A. IV, 9; Ll. 40; Ltr. 3/1/8; predorsal scales 9; scales around caudal peduncle 10.

As percent of standard length: Body depth 30.00, head length 28.00, eye diameter 8.00, snout length 9.00, Interorbital distance, 7.00 head depth 10.00, predorsal distance 74.00, spinous doral height 12.00, spinous dorsal base 35.00, soft dorsal height 14.00, soft dorsal base 13.00, anal height 18.00, anal base 12.00, pectoral length 19.00, pelvic length 17.00, depth of caudal peduncle 8.00.

Body moderately elongate; dorsal profile of head slightly convex; snout pointed; lower jaw longer and projects out; preopercular spine short and less than eye diameter.

Colour: Body silvery-pink, centre of scales light red and borders silvery. Snout and head light red. Spinous dorsal fin black, tips white

and the base of membrane with diagonal white spots, large anteriorly. Caudal lobes red, hind margins yellowish-orange, soft dorsal and anal yellowish-orange. Pectoral pale red and pelvic fins white.

Distribution: From east African coast, India (Lakshadweep) to Japan and French Polynesia.

2. SARGOCENTRON PRASLIN (LACÉPÈDE, 1802)

(Brown spot squirrelfish)

(Photo 22)

Material examined: Two specimens caught in gillnets from south Andaman Island measuring 131 and 138 mm SL.

DESCRIPTION

D. XI, 13; P. 13, V. I, 7; A. IV, 9; C. 18 Ll. 32 - 35; Ltr 3/1/7; scales around caudal peduncle 10; predorsal scales 8 - 9.

As percent of standard length: Body depth 37.90, head length 33.70, eye diameter 12.60, snout length 3.90 - 4.21, interorbital distance 17.25 - 17.90, head depth 30.50, predorsal distance 36.84 - 37.90, prepelvic distance 39.65 - 40.00, preanal distance 73.96 - 77.90, height of spinous dorsal 20.00, spinous dorsal base 45.63 - 49.50, height of soft dorsal 14.30 - 15.50, anal height 23.00 - 23.20, and base 17.60 - 17.90, pectoral length 23.20, pelvic length 23.20, depth of caudal peduncle 9.00 - 9.47, preopercular spine 8.36 - 8.42.

Body deep, dorsal profile of the head convex, ventral profile straight upto origin of anal fin, first sub-orbital bone with 1 or 2 short lateral spines near upper margin, preopercular spine about 3/4 eye diameter.

Colour: Body with alternate horizontal stripes of silvery white and red, the pattern somewhat less pronounced above lateral line. An elongate brown spot beneath soft dorsal and above the base of soft portion of anal fin. Spinous dorsal fin red with white spots, the membrane tipped white. A dark brown spot at the axil of the pectoral.

Distribution: East coast of Africa, India (Andaman Islands), French Polynesia.

HAEMULIDAE

3. PLECTORHINCHUS GATERINUS (FORSSKÅL, 1775)

(Black spotted rubberlip)

(Figure 8)

Material examined: Eight specimens, 90 to 125 mm SL collected from perch-trap catches from Appa Island, Gulf of Mannar and Keelakkarai fish market. All specimens caught were in their juvenile colour phase or in a transformation stage.

DESCRIPTION

D. XIII, 18 - 22 (18 in 4, 20 in 2, 22 in 2); P. 12-14 (12 in 5, 14 in 3) V. I, 7; A III, 7; C. 14-15 (14 in 7, 15 in 1); Ll. 53-58 (53 in 6, 58 in 2); Ltr. 18/1/29; scales around caudal peduncle 19-20; predorsal scales 10-12.

As percent of standard length: Body depth 39.60 - 41.00 (40.20), head length 30.20 - 33.40 (31.91), eye diameter 6.55 - 7.30 (7.01), snout length 7.55 - 8.00 (7.71), interorbital distance 22.60 - 23.00, head depth 34.30 - 36.20 (35.08), predorsal distance 3.77 - 4.50 (4.04), prepelvic distance 35.00 - 36.67), preanal distance 61.00 - 63.10 (62.10), height of spinous dorsal 9.20 - 9.75 (9.49), spinous dorsal base 34.90 - 36.00 (35.62), height of soft dorsal 15.00 - 15.50 (15.24), anal height 20.80 - 22.40 (21.57) and base 11.00 - 11.83 (11.52), pectoral length 15.00 - 16.20 (15.77), pelvic length 17.00 - 19.30 (18.66), depth of caudal peduncle 11.30 - 13.80 (12.68).

Dorsal profile of head and body relatively convex in juveniles, lips fleshy but not swollen, chin with 6 pores but no median pit, second anal spine stouter and slightly longer than third anal spine.

Colour: Body colour pale grey, fins bright yellow, 7 longitudinal bands originating from the head region, the central lines pass through the eye. Few irregular dark blotches on soft dorsal, anal and caudal fins. Pectoral and pelvic fins transparent. The longitudunal bands in juveniles (Fig. 8 A) break into lines of spots in larger specimens (above 115 mm SL) (Fig. 8 B).

Distribution: East coast of Africa, Red sea, Gulf of Aden, Madagascar, the Comoro and Reunion Islands, Mauritius and India (Gulf of Mannar).

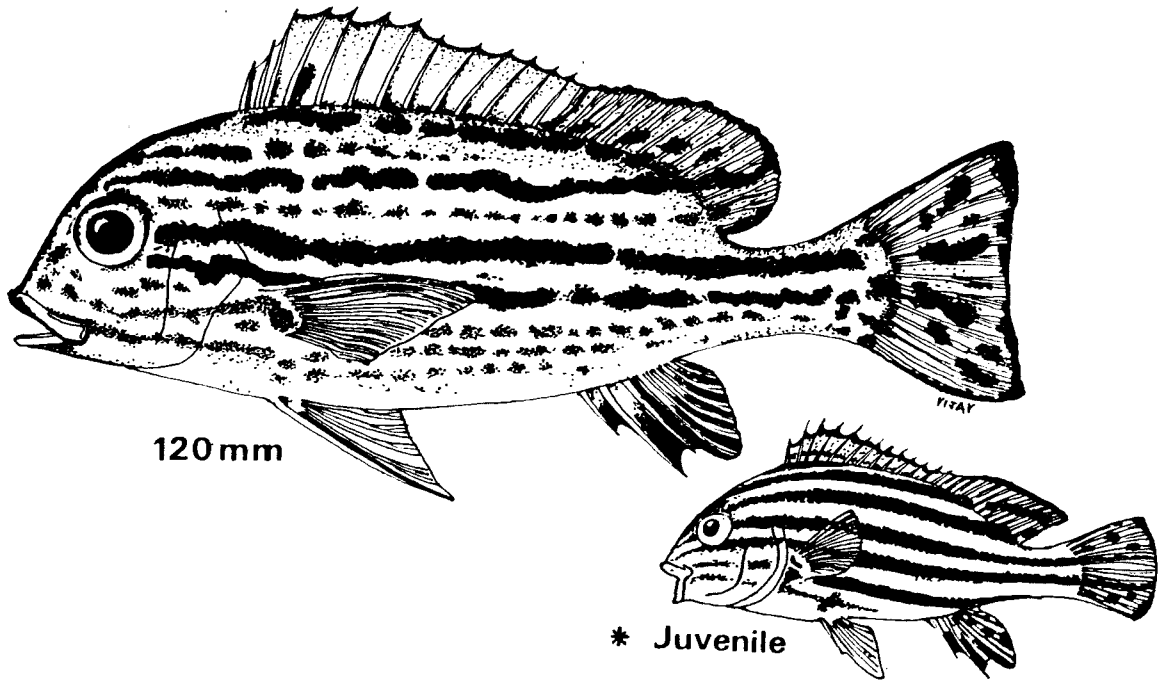


Figure 8. Plectorhinchus gaterinus (Forsskål, 1775)

* Figure taken from Fischer and Bianchi (1984)

CHAETODONTIDAE

4. CHAETODON OXYCEPHALUS BLEEKER 1853

(Photo 23)

Material examined: One specimen, 73 mm SL, collected from perch-trap catches from Appa Island, Gulf of Mannar.

DESCRIPTION

D. XI, 24; P. 15; V. 9; A. III, 20; Ll. 32; Ltr. 6/1/13 predorsal scales 25 (small scales).

As percent of standard length: Body depth 66.70, head length 45.20, eye diameter 9.52, snout length 11.90 interorbital distance 19.00, head depth 38.00, predorsal distance 47.60, prepelvic distance 42.90, preanal distance 71.40, height of spinous dorsal 11.90, spinous dorsal base 35.70, height of soft dorsal 16.00, soft dorsal base 42.90, and height 14.30, anal base 38.00, pectoral length 23.80, pelvic length 21.40, depth of caudal peduncle 9.52.

Body laterally compressed and deep, snout robust, gape horizontal to oblique; sixth dorsal spine longest, first two dorsal spines sub-equal, second anal spine slightly longer than third, first anal spine half the length of the second spine; dorsal and anal fins with blunt angles.

Colour: Seventeen vertical thin black lines across body. Hoof-shaped mark on nape, separated from the eye bands that connect across upper

interorbital space. A large lunate band extending from last spines of the spinous dorsal to lower edge of caudal peduncle. A narrow stripe on the base of soft portion of anal appears to be confluent with the above band.

Distribution: India (Gulf of Mannar), Sri Lanka, Malay Archipelago, Indonesia, Philippines, Palau Islands and New Guinea.

5. FORCIPIGER LONGIROSTRIS (BROUSSONET, 1782)

(Black long-nosed butterflyfish)

(Figure 9)

Material examined: Five specimens, 115 to 132 mm SL, collected from Kavaratti atoll using drive - in - nets from the reef slope region.

DESCRIPTION

D. XI, 24; P. 15; V. 13; A. III, 18; C. 14; Ll. 66 - 75 (66 in 3, 74 in 1, 75 in 1); Ltr 8/1/26; predorsal scales 28-30 (28 in 2, 30 in 3).

As percent of standard length: Body depth 44.20 - 46.00 (45.26), head length 50.20 - 52.90 (51.71), eye diameter 5.40 - 6.00 (5.61), snout length 33.00 - 34.90 (33.81), interorbital distance 6.20 - 7.00 (6.74), head depth 23.30 - 25.00 (24.46), predorsal distance 52.10 - 53.00 (52.65), prepelvic distance 54.90 - 56.60 (55.52), preanal distance 79.90 , height of spinous dorsal 22.65 - 23.30 (22.97), spinous dorsal base 33.00 - 35.26 (34.48), height of soft dorsal 6.98 - 7.25 (7.08), soft dorsal base 24.10 - 26.23 (25.66), and height 19.00 - 19.50 (19.28), anal base 35.46 - 38.53 (36.52), pectoral length 27.86 - 29.50 (28.72), pelvic length 23.50 - 24.80 (24.04), depth of caudal peduncle 5.43 - 6.20 (5.90).

Body laterally compressed and deep, dorsal profile convex, ventral profile straight, snout extremely elongate, pointed slightly upwards appearing like an eye dropper, mouth opening very small.

Colour: Body chrome yellow. A dark traingular section on the side of head connects with the one from the opposite side at the nape but is separate from just below nape to near end of lachrymal, connecting again at the end of lachrymal. A narrow brown stripe of varying intensity and length extends along the upper part of the snout. Chest region with brown spots. Faint discontinuous patches of brown on yellowish body. Fins yellow except pectoral which is hyaline. Posterior margins of soft dorsal and anal with a blue hue followed by a dark subterminal band. Posterior angle of soft anal with a round black spot, smaller than eye.

Distribution: Burgess (1978) stated that the exact distribution of F. longirostris is not known since the species has until recently been confused and combined with F. flavissimus. However F. longirostris is recognised from Madagascar, Comoro Islands, Reunion Islands, Mauritius, India (Lakshadweep), Indonesia, Philippines, Japan, Marianias Islands, Guam, New Guinea, Great Barrier Reef, Solomon Islands Marshall Islands, Wake Island, Hawaii and Tuamotu archipelago.

Taxonomic note: Two specimens of Forcipiger flavissimus Jordan and Mc Gregor, 1898, measuring 112 and 114 mm SL have been collected from Kavaratti atoll, indicating that these two species coexist in Lakshadweep. F. flavissimus differs from F. longirostris in having XII Dorsal spines and

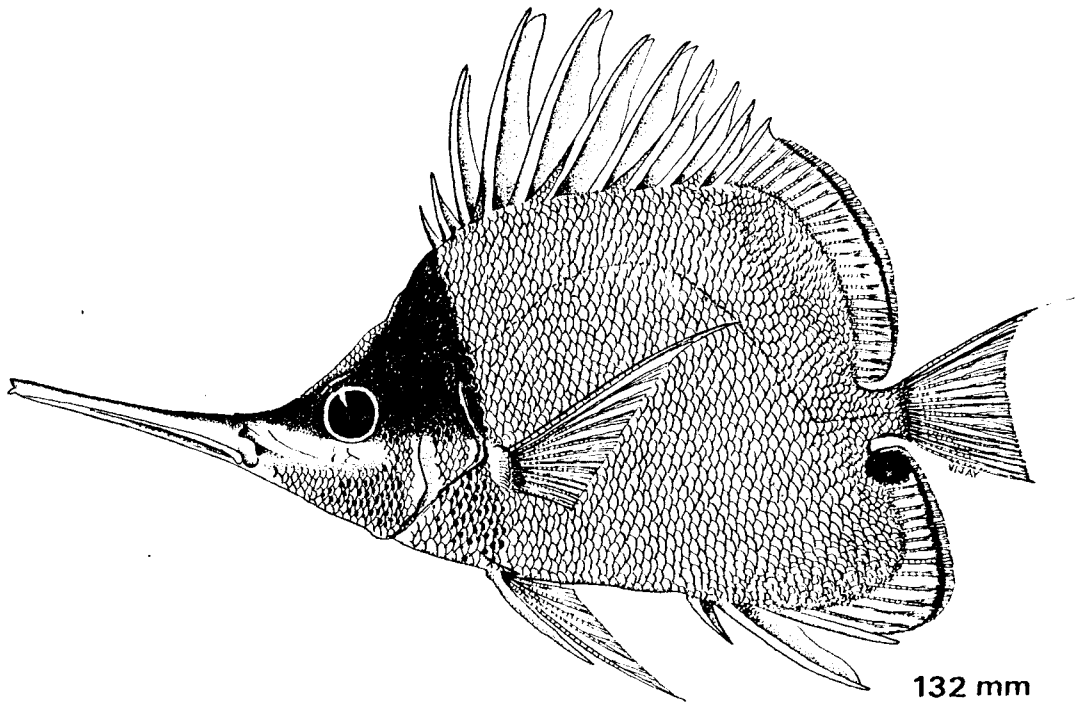


Figure 9. Forcipiger longirostris (Broussonet, 1782)

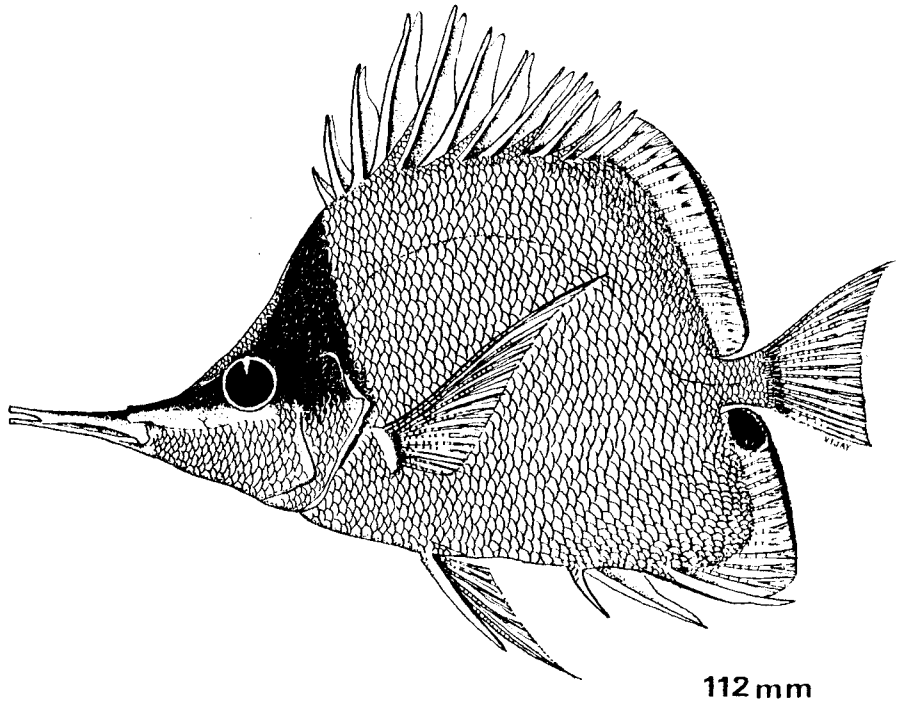


Figure 10. Forcipiger flavissimus Jordan and Mc Gregor, 1898.

a relatively shorter snout appearing like a forceps (28.60% in SL) and in not having brown spots and faint brown patches on the body. Fig. 10 (F. flavissimus) has been included for comparison.

FAMILY : POMACANTHIDAE

6. APOLEMICHTHYS TRIMACULATUS (LACÉPÈDE, 1831)

(Three spot angelfish)

(Figure 11)

Material examined: Single specimen, 143 mm SL obtained by spearing at Suheli atoll, Lakshadweep.

DESCRIPTION

D. XIV, 16; P. 17; V. I, 9; A. III, 17; C. 18; Ll. 46; Ltr. 8/1/20; scales around caudal peduncle 18; predorsal scales 12.

As percent standard length: Body depth 51.00, head length 25.50, eye diameter 7.45, snout length 10.60, interobital distance 12.90, head depth 34.00, predorsal distance 29.80, prepelvic distance 34.00, preanal distance 55.30, height of spinous dorsal 9.57, spinous dorsal base 40.40, height of soft dorsal 14.90, soft dorsal base 31.90, anal height 18.00, and base 34.00, pectoral length 21.30, pelvic length 21.30, depth of caudal peduncle 13.80, preopercular spine 9.57.

Body laterally compressed, symetrical and slightly robust, head profile concave in front of eye rising sharply to dorsal origin, snout blunt, posterior margins of dorsal and anal fins with blunt angles, caulal fin round.

Colour: Body and fins (except anal) uniformly bright yellow. A broad black band from middle to the margin of the anal fin, while the rest of the portion is creamy - yellow. A black spot, smaller than eye, on the dorsal prfile of the head (spot closer to first dorsal spine than to eye). A black spot just behind the head and above the pectoral base. Snout blue. Preopercular spine edged with pale blue.

Distribution: Widely distributed in the Indo-Pacific. Within the Indian region, it is now reported from Lakshadweep.

FAMILY : LABRIDAE

7. LABROIDES BICOLOR FOWLER AND BEAN, 1928

(Bicoloured cleaner wrasse)

(Figure 12)

Material examined: Two specimens, 63 and 102 mm SL collected by seine nets from Kalpeni atoll, Lakshadweep.

DESCRIPTION

D. IX, 11; P. 13; V. 8; A. III, 10; C. 22; Ll. 19 + 8; Ltr 4/1/12 scales around caudal peduncle 16; predorsal scales 9-13.

As percent of standard length: Body depth 23.30 - 25.00; head length 28.07 - 29.10; eye diameter 5.83; snout length 8.00 - 8.74; interorbital distance 6.80; head depth 19.40; predorsal distance 31.00 - 32.43; prepelvic distance 34.83 - 35.90; preanal distance 60.20 - 63.10; height of spinous dorsal 4.85; spinous dorsal base 27.20; height of soft dorsal 9.71;

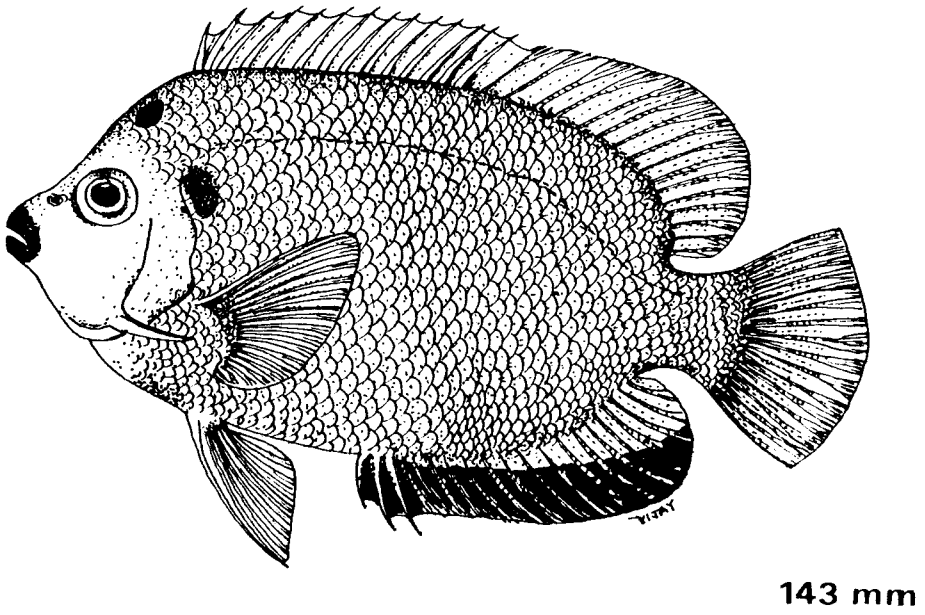


Figure 11. Apolemichthys trimaculatus (Lacépède, 1831)

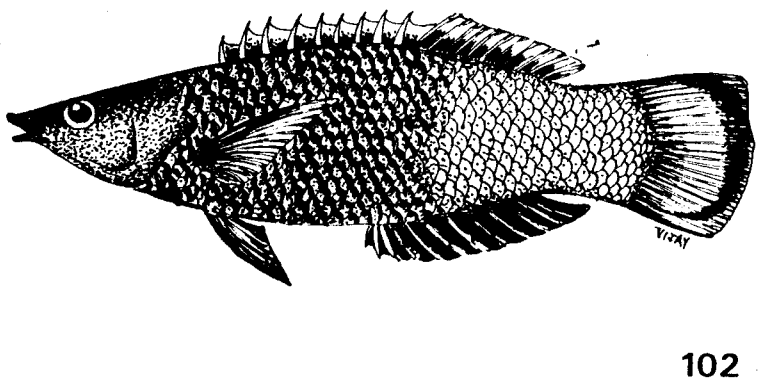


Figure 12. Labroides bicolor Fowler and Bean, 1928

soft dorsal base 21.40 - 23.00; anal height 9.71; anal base 32.00 - 33.83; pectoral length 16.00 - 17.50; pelvic length 11.70; depth of caudal peduncle 17.50 - 19.30.

Body elongate and streamlined, snout sharp, upper jaw longer than the lower, caudal peduncle deep, caudal round.

Colour: Head dark blue. Middle portion of body, ventrals, dorsal and anal fins black. Posterior half of body, below the soft dorsal and caudal fin yellowish - white. A black crescent-shaped marking on caudal fin. Margins of soft dorsal fin hyaline. Membrane of spinous dorsal tipped white.

Distribution: Indo-Pacific. Within the Indian region, it is now reported from Lakshadweep.

FAMILY : SCARIDAE

8. SCARUS RUBROVIOLACEUS BLEEKER, 1847

(Figure 13)

Material examined: Two specimens measuring 260 and 283 mm SL and one specimen 383 mm SL collected by seine nets at Kalpeni atoll, Lakshadweep.

DESCRIPTION

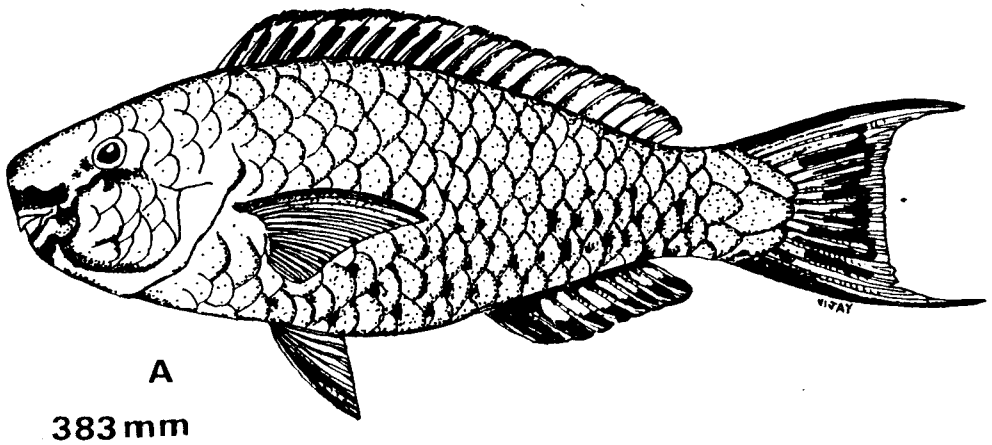
D. IX, 10 - 13 (10 in 2, 13 in 1); P. 14; V. 6; A. III, 6-9 (6 in 2, 9 in 1); C. 14; Ll. 19 + 7; Ltr 2/1/7; scales around caudal peduncle 8; preodrsal scales 6-8 (6 in 2, 8 in 1), 3 rows of cheek scales.

As percent of standard length: Body depth 32.68 - 34.70 (33.79), head length 28.13 - 29.60 (28.96), eye diameter 3.06, snout length 11.00 - 12.20 (11.57), interorbital distance 8.16, head depth 23.60 - 25.50 (24.25), predorsal distance 34.70 - 36.15 (35.19), prepelvic distance 30.60 - 32.00 (31.53), preanal distance 59.20, height of dorsal 8.16 - 9.30 (8.54), dorsal base 55.00 - 56.10 (55.37), anal height 14.30, anal base 22.40, pectoral length 21.25 - 22.40 (21.88), pelvic length 18.40, depth of caudal peduncle 12.73 - 13.30 (13.01).

Head profile rising sharply from above mouth creating a hump in front of the head, caudal fin produced into caudal lobes. Teeth fused in upper and lower jaws to form dental plates which are mostly covered by lips in the specimen measuring 383 mm SL (Fig. 13 A).

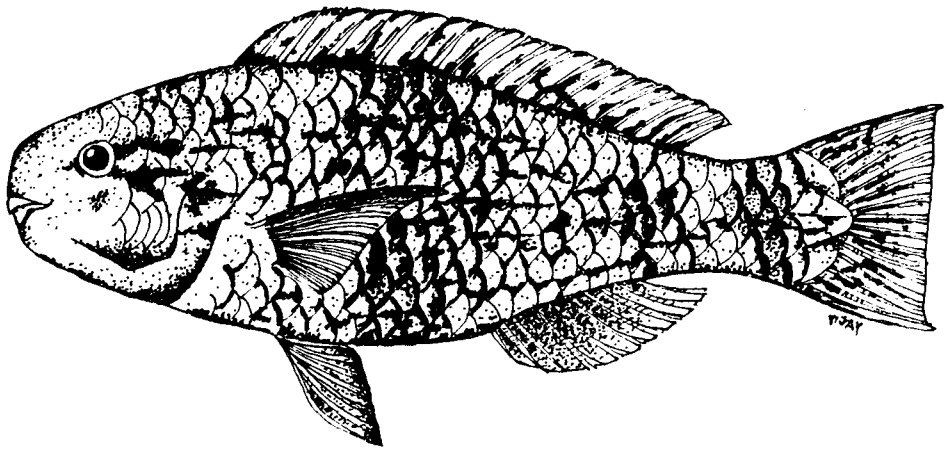
Head profile straight without creating a hump in front of head; Caudal trauncate and caudal lobes not extended in specimens measuring 260 - 283 mm SL (Fig. 13 B).

Colour: In the specimen measuring 383 mm SL the body was greenish-blue. Dorsal region green, shading to bluish yellow on sides. Scales edged in organe, becoming pale blue ventrally. Edge of upper lip pink with a broad blue band above it. Edge of lower lip blue. Chin pinkish with a broad blue band that is directed dorsally to join the band on the upper lips, thereafter passing beneath the eye and fading off. A blue streak on the lower side of cheek, joining the preopercle margin. Dorsal fin orange with a blue border and a streak of blue along each ray. Caudal fin and



A

383 mm



B

260 mm

Figure 13. Scarus rubroviolaceus Bleeker, 1847.

lobes blue with an irregular orange pattern at the base. Anal fin orange with a broad blue margin and a narrow blue line along the base. Pectorals blue, gradually fading towards the margin. Anterior margin of pelvic fins blue followed by orange (Fig. 13 A).

Body pinkish-grey on dorsal region. Snout reddish, ventral side light red. Hind border of scales with black margins, few scales on body with broader, irregular black blotches. Dorsal, anal and caudal light red, ventral red. Upper part of pectoral red and lower part hyaline in specimens measuring 260 - 283 mm SL (Fig. 13 B).

Distribution: East African coast, estward to Madagascar, Seychelles, Mauritius, Maldives, India (Lakshadweep), Sri Lanka, Eastern Indian Ocean, western central Pacific, eastward to Gulf of California and Panama.

FAMILY : SIGANIDAE

9. SIGANUS LURIDUS (RÜPPELL, 1828)

(Dusky Spinefoot)

(Figure 14)

Material examined: Sixteen specimens, 65 to 105 mm SL, collected from the perch trap catches from Appa Island, Gulf of Mannar.

DESCRIPTION

D. XIII, 10 - 13 (10 in 10, 13 in 6), P. 16-18 (16 in 14, 18 in 2), V. 5 - 6 (5 in 15, 6 in 1), A. VII, 9 - 10 (9 in 15, 10 in 1), C. 18 - 20 (18

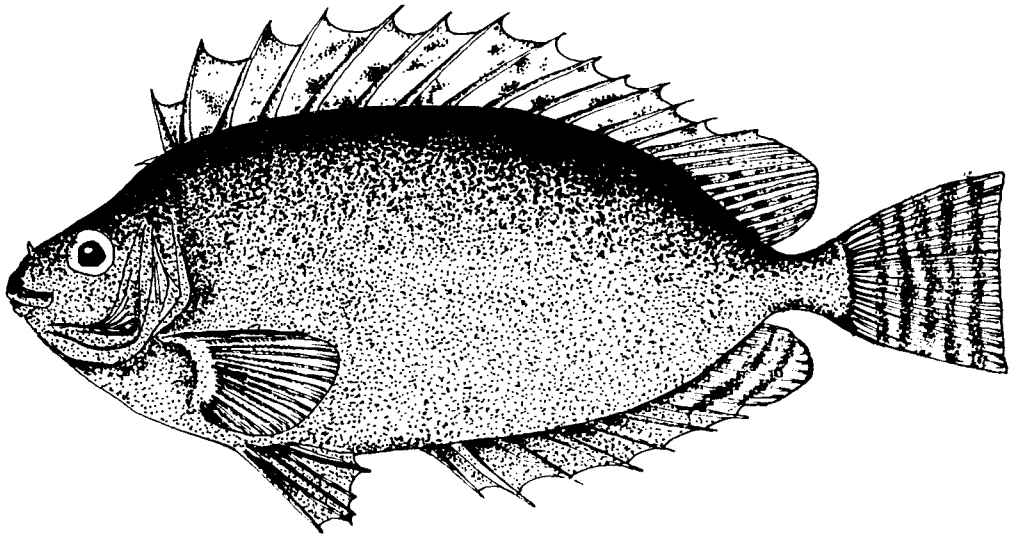


Figure 14. Siganus luridus (Rüppell, 1828)

Figure taken from Fischer and Bianchi (1984).

in 14, 20 in 2); Ll. 159 - 163 (159 in 12, 162 in 2, 163 in 2); Ltr. 20/1/55 predorsal scales 15 - 17 (15 in 4, 17 in 12).

As percent of standard length: Body depth 39.40 - 42.30 (41.11), head length 20.16 - 22.87 (21.50), eye diameter 5.77 - 5.90 (5.85), snout length 6.90 - 9.30 (7.97), interorbital distance 5.77, head depth 18.60 - 20.20 (19.26) predorsal distance 26.00 - 26.50 (26.25), prepelvic distance 33.70 - 35.00 (34.27), preanal distance 52.36 - 54.80 (53.89), height of spinous dorsal 14.30 - 16.30 (15.26), spinous dorsal base 54.00 - 57.70 (56.20), height of soft dorsal 12.75 - 13.50 (13.00), soft dorsal base 19.20 - 20.00 (19.71), height of anal 11.50 - 13.00 (12.49), anal base 43.78 - 46.20 (45.54), pectoral length 19.40 - 22.00 (20.35), pelvic length 12.63 - 14.40 (13.88), depth of caudal peduncle 6.25 - 7.00 (6.63).

Body elongate and laterally compressed, snout blunt, anterior nostril with a fleshy flap, a sharp spine projects forward in front of first dorsal spine which is shortest, caudal truncate.

Colour: Uniformly dark brown with pectoral and dorsal fins relatively pale to yellowish.

Distribution: East coast of Africa, Seychelles, Mauritius, India (Gulf of Mannar), Red sea and Mediterranean.

B. DISTRIBUTION OF FISHES IN THE FOUR CORAL REEF ECOSYSTEMS OF INDIA.

A list of species recorded during the present study made during January 1991 to June 1992 from Lakshadweep, Andaman Islands, Gulf of Mannar and Gulf of Kutch incorporating those species reported earlier is given in Table 1.

Table 1 : Distribution of different fish species in the four coral reef ecosystems of India

(● indicates that the species is known from the region; O indicates that the species has not been reported from the region; N indicates a new distributional record for the region; * indicates a new distributional record from the Indian region; LAK = Lakshadweep Islands; AND = Andaman Islands; GOM = Gulf of Mannar; GOK = Gulf of Kutch).

S.No. (1)	Species (2)	LAK (3)	AND (4)	GOM (5)	GOK (6)
	MURAENIDAE				
1.	Anarchias cantonensis (Schultz, 1943)	●	O	O	O
2.	Anarchias fuscus Smith 1962	●	●	O	O
3.	Echinda delicatula (Kaup, 1856)	●	O	O	O
4.	Echinda leucotaenia Schultz, 1943	●	O	O	O
5.	Echinda nebulosa (Ahl, 1789)	●	O	●	O
6.	Echinda polyzona (Richardson, 1845)	●	O	O	O
7.	Echinda zebra (Shaw, 1791)	●	●	O	O
8.	Enchelynassa canina (Quoy & Gaimard, 1824)	●	O	O	O
9.	Gymnothorax buroensis (Bleeker, 1857)	●	O	O	O
10.	Gymnothorax favagineus (Bloch & Schneider 1801)	O	●	●	●
11.	Gymnothorax fimbriatus (Bennett, 1831)	●	O	O	O
12.	Gymnothorax flavimarginatus (Rüppell, 1830)	●	●	O	O
13.	Gymnothorax hepaticus (Rüppell, 1828)	O	●	O	O
14.	Gymnothorax javanicus (Bleeker, 1859)	●	O	O	O
15.	Gymnothorax monochrous (Bleeker, 1856)	●	●	O	O
16.	Gymnothorax monostigmus (Regan, 1909)	●	O	O	O
17.	Gymnothorax permistus (Smith, 1962)	●	O	O	O
18.	Gymnothorax pseudothyrsoidea (Bleeker, 1852)	●	O	O	O
19.	Gymnothorax punctatus (Bloch & Schneider, 1801)	O	O	●	O
20.	Gymnothorax richardsoni (Bleeker, 1852)	●	●	O	O
21.	Gymnothorax rueppelliae (Mc Clelland, 1845)	●	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
22.	Gymnothorax undulatus (Lacépède, 1803)	●	●	●	●
23.	Siderea picta (Ahl, 1789)	●	●	O	O
24.	Siderea thyrsoidea (Richardson, 1844)	O	●	O	O
25.	Thyrsoidea macrura (Bleeker 1854)	O	●	●	O
26.	Uropterygius marmoratus (Lacépède, 1803)	●	●	O	O
27.	Uropterygius tigrinus (Lesson, 1829)	O	●	O	O
	HOLOCENTRIDAE				
28.	Holocentrus laevis Günther, 1859	●	O	O	O
29.	Holocentrus lacteoguttatus Cuvier, 1829	●	O	O	O
30.	Myripristis adusta Bleeker, 1853	●	O	O	O
31.	Myripristis murdjan (Forsskål, 1775)	●	●	O	O
32.	Neoniphon opercularis (Valenciennes, 1831)	*	O	O	O
33.	Neoniphon sammara (Forsskål, 1775)	●	O	O	O
34.	Sargocentron caudimaculatum (Rüppell, 1838)	●	●	O	O
35.	Sargocentron diadema (Lacépède, 1801)	●	●	●	O
36.	Sargocentron melanospilos (Bleeker, 1858)	O	●	O	O
37.	Sargocentron praslin (Lacépède, 1802)	O	*	O	O
38.	Sargocentron rubrum (Forsskål, 1775)	O	●	●	O
39.	Sargocentron spiniferum (Forsskål, 1775)	●	●	O	O
40.	Sargocentron violaceum (Bleeker, 1853)	●	O	O	O
	SERRANIDAE				
41.	Aethaloperca rogaa (Forsskål, 1775)	O	O	O	O
42.	Anthias cooperi Regan 1902				
43.	Anthias squamipinnis Peters 1855				
44.	Anthias cichlops (Bleeker, 1853)				
45.	Cephalopholis argus Schneider, 1801	●	●	O	O
46.	Cephalopholis boenack (Bloch, 1790)	●	●	●	O
47.	Cephalopholis formosa (Shaw, 1804)	●	O	N	O
48.	Cephalopholis leopardus (Lacépède, 1802)	O	●	O	O
49.	Cephalopholis miniata (Forsskål, 1775)	●	●	●	O

(1)	(2)	(3)	(4)	(5)	(6)
50.	Cephalopholis nigripinnis (Valencinnes, 1828)	O	●	O	O
51.	Cephalopholis sonnerati (Valenciennes, 1828)	●	●	O	O
52.	Cromileptes altivelis (Valenciennes, 1828)	O	●	O	O
53.	Epinephelus areolatus (Forsskål, 1775)	O	●	O	O
54.	Epinephelus caeruleopunctatus (Bloch, 1790)	●	●	O	O
55.	Epinephelus corallicola Cuvier & Valenciennes 1828	●	O	O	O
56.	Epinephelus fasciatus (Forsskål, 1775)	●	●	O	●
57.	Epinephelus faveatus (Valenciennes, 1828)	O	O	N	O
58.	Epinephelus flavocaeruleus (Lacépède, 1802)	●	●	O	O
59.	Epinephelus fuscoguttatus (Forsskål, 1775)	●	●	●	O
60.	Epinephelus hexagonatus (Schneider, 1801)	●	O	●	O
61.	Epinephelus longispinus (Kner, 1865)	●	●	O	O
62.	Epinephelus malabaricus (Schneider, 1801)	O	●	●	O
63.	Epinephelus melanostigma Schultz, 1953	●	O	O	O
64.	Epinephelus merra Bloch, 1793	●	●	●	●
65.	Epinephelus morrhua (Valenciennes, 1833)	●	●	O	O
66.	Epinephelus summana (Forsskål, 1775)	O	●	O	O
67.	Epinephelus tauvina (Forsskål, 1775)	●	●	●	●
68.	Epinephelus undulosus (Quoy & Gaimard, 1824)	O	●	●	O
69.	Plectropomus maculatus (Bloch, 1790)	●	●	O	●
70.	Promicrops lanceolatus (Bloch, 1790)	O	O	●	O
71.	Variola louti (Forsskål, 1775)	●	●	O	●
	PLESIOPIDAE				
72.	Plesiops coeruleonineatus Rüppell, 1835	O	O	O	O
	APOGONIDAE				
73.	Apogon apogonides (Bleeker, 1856)	●	O	O	O
74.	Apogon aureus (Lacépède, 1802)	O	●	O	O
75.	Apogon chrysotaenia Bleeker, 1851	O	●	O	O
76.	Apogon coccineus Rüppell, 1838	●	O	O	O
77.	Apogon enneastigma Rüppell	O	O	●	O

(1)	(2)	(3)	(4)	(5)	(6)
78.	Apogon guamensis Valenciennes, 1832	●	O	O	O
79.	Apogon hyalosoma Bleeker, 1852	O	●	O	O
80.	Apogon kallopterus Bleeker, 1856	●	O	O	O
81.	Apogon leptacanthus Bleeker, 1856	●	O	O	O
82.	Apogon multitaeniatus Ehrenberg 1828	O	●	O	O
83.	Apogon nitidus (Smith, 1961)	●	●	O	O
84.	Apogon savayensis Günther, 1871	●	●	●	O
85.	Apogon septemstriatus Günther, 1880	O	●	●	O
86.	Apogon taeniateus Ehrenberg, 1828	O	●	O	O
87.	Apogon taeniophorus Regan, 1908	●	●	●	O
88.	Apogon thermalis Cuvier, 1829	●	●	O	O
89.	Archamia fucata (Cantor, 1850)	●	O	O	O
90.	Archamia lineolata (Ehrenberg, 1828)	O	●	O	O
91.	Archamia macroptena Cuvier	O	●	O	O
92.	Cheilodipterus artus Smith, 1961	O	●	O	O
93.	Cheilodipterus lachneri Klausewitz, 1959	●	O	O	O
94.	Cheilodipterus macrodon (Lacépède, 1802)	O	●	O	O
95.	Cheilodipterus quinquelineatus Cuvier, 1828	●	●	●	O
96.	Foa brachygramma (Jenkins, 1903)	●	O	O	O
97.	Fowleria aurita (Valenciennes, 1831)	●	●	O	O
98.	Gymnapogon africanus Smith, 1954	●	O	O	O
99.	Ostorhynchus moluccensis (Valenciennes, 1832)	●	O	O	O
100.	Pristiapogon fraenatus (Valenciennes, 1832)	●	O	O	O
101.	Pseudamia gelatinosa Smith, 1954	●	O	O	O
102.	Rhabdamia cypselurus Weber, 1909	●	O	O	O
103.	Rhabdamia gracilis (Bleeker, 1856)	●	O	O	O
104.	Sphaeramia orbicularis (Kuhl & van Hasselt 1828)	O	●	O	O
	MALACANTHIDAE				
105.	Malacanthus brevirostris Guichenot, 1848	O	●	O	O
106.	Malacanthus latovittatus (Lacépède, 1801)	●	●	●	O

(1)	(2)	(3)	(4)	(5)	(6)
	LUTJANIDAE				
107.	Aphareus furca (Lacépède, 1801)	●	●	O	O
108.	Aphareus rutilans Cuvier, 1830	O	●	O	O
109.	Aprion virescens Valenciennes, 1830	●	O	O	O
110.	Lutjanus argentimaculatus (Forsskål, 1775)	●	●	●	O
111.	Lutjanus bengalensis (Bloch, 1790)	●	O	O	O
112.	Lutjanus biguttatus (Valenciennes, 1830)	O	●	O	O
113.	Lutjanus bohar (Forsskål, 1775)	●	●	O	O
114.	Lutjanus decussatus (Cuvier, 1828)	O	●	●	O
115.	Lutjanus ehrenbergii (Peters, 1869)	O	●	O	O
116.	Lutjanus fulviflamma (Forsskål, 1775)	●	●	●	●
117.	Lutjanus fulvus (Schneider, 1801)	●	●	●	O
118.	Lutjanus gibbus (Forsskål, 1775)	●	●	O	O
119.	Lutjanus johni (Bloch, 1792)	O	●	●	●
120.	Lutjanus kasmira (Forsskål, 1775)	●	●	●	O
121.	Lutjanus lunulatus (Mungo Park, 1797)	O	●	O	O
122.	Lutjanus lutjanus Bloch, 1790	O	●	O	O
123.	Lutjanus malabaricus (Schneider, 1801)	O	●	N	●
124.	Lutjanus monostigma (Cuvier, 1828)	O	●	O	O
125.	Lutjanus quinquelineatus (Bloch, 1790)	O	O	●	O
126.	Lutjanus rivulatus (Cuvier, 1828)	O	●	●	O
127.	Lutjanus russellii (Bleeker, 1849)	●	●	O	O
128.	Lutjanus sebae (Cuvier, 1816)	O	●	O	O
129.	Lutjanus vittus (Quoy & Gaimard, 1824)	O	●	N	O
130.	Macolor niger (Forsskål, 1775)	●	●	O	O
131.	Pinjalo pinjalo (Bleeker, 1850)	O	●	●	O
132.	Pristipomoides typus Bleeker, 1852	O	●	O	O
	CAESIONIDAE				
133.	Caesio caerulaureus Lacépède, 1801	●	●	●	O
134.	Caesio lunaris (Valenciennes, 1830)	O	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
135.	Caesio xanthonotus Bleeker, 1853	●	●	O	O
136.	Gymnocaesio argenteus (Bloch, 1790)	●	O	O	O
137.	Pterocaesio chrysozona (Valenciennes, 1830)	●	●	O	O
138.	Pterocaesio pisang (Bleeker, 1853)	●	O	O	O
139.	Pterocaesio tile (Valenciennes, 1830)	●	O	O	O
	HAEMULIDAE				
140.	Diagramma pictum (Thunberg, 1792)	O	●	●	●
141.	Plectorhinchus albovittatus (Rüppell, 1835)	●	O	O	O
142.	Plectorhinchus gaterinus (Forsskål, 1775)	O	O	*	O
143.	Plectorhinchus gibbosus (Lacépède, 1802)	●	●	O	O
144.	Plectorhinchus orientalis (Bloch, 1793)	●	O	●	O
145.	Plectorhinchus schotaf (Forsskål, 1775)	O	O	●	●
	LETHRINIDAE				
146.	Gnathodontex aureolineatus (Lacépède, 1802)	●	●	O	●
147.	Gymnocranius griseus (Schlegel, 1844)	●	O	O	O
148.	Lethrinus cinereus Valenciennes, 1830	O	O	●	O
149.	Lethrinus concyliatus (Smith, 1959)	O	●	O	O
150.	Lethrinus elongatus Valenciennes, 1830	O	O	●	●
151.	Lethrinus frenatus (Valenciennes 1830)	O	●	O	●
152.	Lethrinus harak (Forsskål, 1775)	●	●	●	O
153.	Lethrinus lentjan (Lacépède, 1802)	O	O	●	O
154.	Lethrinus mahsena (Forsskål, 1775)	●	O	O	O
155.	Lethrinus mahsenoides Valenciennes, 1830	O	O	●	O
156.	Lethrinus microdon Valenciennes, 1830	●	O	●	O
157.	Lethrinus nebulosus (Forsskål, 1775)	O	O	●	O
158.	Lethrinus ornatus Valenciennes, 1830	N	●	O	O
159.	Lethrinus ramak (Forsskål, 1775)	●	O	●	●
160.	Lethrinus rhodopterus Bleeker, 1852	O	●	O	O
161.	Lethrinus variegatus Ehrenberg, 1830	O	O	●	O
162.	Lethrinus xanthocheilus Klunzinger, 1870	●	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
163.	Monotaxis grandoculis (Forsskål, 1775)	●	●	O	O
	MULLIDAE				
164.	Mulloides flavolineatus (Lacépède, 1801)	●	●	O	O
165.	Parupeneus barberinus (Lacépède, 1801)	●	●	O	O
166.	Parupeneus bifasciatus (Lacépède, 1801)	●	O	O	O
167.	Parupeneus cinnabarinus (Cuvier, 1829)	O	●	●	O
168.	Parupeneus cyclostomus (Lacépède, 1801)	●	●	O	O
169.	Parupeneus indicus (Shaw, 1803)	●	●	●	O
170.	Parapeneus macronema (Lacépède, 1801)	●	●	●	O
171.	Parupeneus pleurostigma (Bennett, 1831)	●	O	O	O
172.	Upeneus bensasi (Temminck & Schlegel, 1842)	O	O	●	O
173.	Upeneus luzonius Jordon & Seale, 1907	O	O	●	O
174.	Upeneus moluccensis (Bleeker, 1855)	O	●	O	O
175.	Upeneus sulphureus Cuvier, 1829	O	●	O	●
176.	Upeneus sundaicus (Bleeker, 1855)	●	O	●	O
177.	Upeneus taeniopterus Cuvier, 1829	●	O	O	O
178.	Upeneus tragula Richardson, 1846	●	●	●	O
179.	Upeneus vittatus (Forsskål, 1775)	●	●	●	●
	CHAETODONTIDAE				
180.	Chaetodon auriga Forsskål, 1775	●	●	●	O
181.	Chaetodon bennetti Cuvier, 1831	●	O	O	O
182.	Chaetodon citrinellus Cuvier, 1831	●	O	O	O
183.	Chaetodon collare Bloch, 1787	●	●	●	●
184.	Chaetodon decussatus Cuvier, 1831	O	O	N	O
185.	Chaetodon falcula Bloch, 1793	●	O	N	O
186.	Chaetodon kleinii Bloch, 1790	●	O	O	O
187.	Chaetodon lunula (Lacépède, 1803)	●	●	O	O
188.	Chaetodon melannotus Bloch & Schneider, 1801	●	O	●	O
189.	Chaetodon meyeri Bloch & Schneider, 1801	●	O	O	O
190.	Chaetodon octofasciatus Bloch, 1787	O	O	●	O

(1)	(2)	(3)	(4)	(5)	(6)
191.	Chaetodon oxycephalus Bleeker, 1853	O	O	*	O
192.	Chaetodon plebeius Cuvier, 1831	N	●	●	O
193.	Chaetodon triangulum Cuvier, 1831	N	N	O	O
194.	Chaetodon trifascialis Quoy & Gaimard, 1825	●	O	N	O
195.	Chaetodon trifasciatus Mungo Park, 1797	●	●	●	O
196.	Chaetodon unimaculatus Bloch, 1787	●	●	O	O
197.	Chaetodon vagabundus Linnaeus, 1758	●	●	●	●
198.	Chaetodon xanthocephalus Bennett, 1832	●	O	●	O
199.	Forcipiger flavissimus Jordon & Mc Gregor, 1898	N	O	O	O
200.	Forcipiger longirostris (Broussonet, 1782)	*	O	O	O
201.	Hemitaurichthys zoster (Bennett, 1831)	●	O	O	O
202.	Heniochus acuminatus (Linnaeus, 1758)	●	●	O	O
203.	Heniochus monoceros Cuvier, 1831	●	●	O	O
204.	Parachaetodon ocellatus (Cuvier, 1831)	O	O	N	O
	POMACANTHIDAE				
205.	Apolemichthys trimaculatus (Lacépède, 1831)	*	O	O	O
206.	Centropyge multispinis (Playfair, 1867)	●	O	O	O
207.	Pomacanthus annularis (Bloch, 1787)	O	O	●	●
208.	Pomacanthus imperator (Bloch, 1787)	●	●	O	O
209.	Pomacanthus semicirculatus (Cuvier, 1831)	●	●	●	●
210.	Pygoplites diacanthus (Boddaert, 1772)	●	O	O	O
	POMACENTRIDAE				
211.	Abudefduf bengalensis (Bloch, 1787)	●	●	O	●
212.	Abudefduf cingulum (Klunzinger, 1871)	●	O	O	O
213.	Abudefduf margaritus (Cuvier, 1830)	O	●	O	O
214.	Abudefduf notatus (Day, 1869)	O	●	O	O
215.	Abudefduf septemfasciatus (Cuvier, 1830)	●	●	●	O
216.	Abudefduf sexfasciatus (Lacépède, 1801)	●	O	O	O
217.	Abudefduf saxatilis (Linnaeus, 1758)	●	●	●	O
218.	Abudefduf sordidus (Forsskål, 1775)	●	●	O	●

(1)	(2)	(3)	(4)	(5)	(6)
219.	Abudefduf xanthozona (Bleeker, 1853)	●	O	O	O
220.	Amblyglyphidodon leucogaster (Bleeker, 1847)	O	●	O	O
221.	Amphiprion akallopisos Bleeker, 1853	O	●	O	O
222.	Amphiprion bicinctus Rüppell, 1828	●	O	O	O
223.	Amphiprion chrysogaster Cuvier, 1830	●	O	O	O
224.	Amphiprion fraenatus Brevoort, 1860	O	●	O	O
225.	Amphiprion nigripes Regan, 1908	●	●	O	O
226.	Amphiprion sebae Bleeker, 1853	O	●	O	O
227.	Chiloprion labiatus (Day, 1878)	O	●	O	O
228.	Chromis caerulea (Cuvier, 1830)	●	●	O	O
229.	Chromis chrysura (Bliss, 1883)	●	O	O	O
230.	Chromis dimidiata (Klunzinger, 1871)	●	O	O	O
231.	Chromis nigrura Smith, 1960	●	O	O	O
232.	Chromis opercularis (Günther, 1867)	●	O	O	O
233.	Chromis ternatensis (Bleeker, 1856)	●	O	●	O
234.	Chromis weberi Fowler & Bean, 1928	●	O	O	O
235.	Chrysiptera biocellata (Quoy & Gaimard 1824)	●	●	O	O
236.	Chrysiptera glauca (Cuvier, 1830)	●	O	O	O
237.	Chrysiptera unimaculata (Cuvier, 1830)	●	O	O	O
238.	Dascyllus aruanus (Linnaeus, 1758)	●	●	●	O
239.	Dascyllus reticulatus (Richardson, 1846)	●	●	O	O
240.	Dascyllus trimaculatus (Rüppell, 1829)	●	●	●	O
241.	Lepidozygus tapeinosoma (Bleeker, 1856)	●	O	O	O
242.	Paraglyphidodon bonang (Bleeker, 1852)	O	●	O	O
243.	Plectroglyphidodon dickii (Lienard, 1839)	●	O	O	O
244.	Plectroglyphidodon lacrymatus (Quoy & Gaimard 1825)	●	O	O	O
245.	Plectroglyphidodon phoenixensis (Schultz, 1943)	●	O	O	O
246.	Pomacentrus albicaudatus Baschieri - Salvadori 1955	●	O	O	O
247.	Pomacentrus albifasciatus Schlegel & Muller, 1839	●	O	O	O
248.	Pomacentrus bifasciatus Bleeker, 1854	O	●	O	O
249.	Pomacentrus littoralis (Cuvier 1830)	●	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
250.	Pomacentrus pavo (Bloch, 1787)	●	O	O	O
251.	Pomacentrus prosopotaenia Bleeker, 1852	O	●	O	O
252.	Pomacentrus sindensis Day, 1873	O	O	O	●
253.	Pomacentrus sulfureus Klunzinger, 1871	●	O	O	O
254.	Pomacentrus trilineatus Cuvier, 1830	●	O	O	O
255.	Pomacentrus tripunctatus Cuvier, 1830	O	●	O	O
256.	Pomacentrus violascens (Bleeker 1852)	O	●	O	O
257.	Stegastes lividus (Schneider, 1801)	●	O	O	O
258.	Stegastes nigricans (Lacépède, 1803)	●	O	O	O
	LABRIDAE				
259.	Anampses meleagrides Valenciennes, 1840	●	O	O	O
260.	Anampses caeruleopunctatus Rüppell, 1829	●	●	O	O
261.	Bodianus axillaris (Bennett, 1831)	N	●	●	O
262.	Bodianus diana (Lacépède, 1801)	O	●	O	O
263.	Bodianus leucosticus (Bennett, 1831)	O	●	O	O
264.	Cheilinus chlorurus (Bloch, 1791)	●	●	●	O
265.	Cheilinus digrammus (Lacépède, 1801)	●	●	O	O
266.	Cheilinus fasciatus (Seale, 1908)	●	●	O	O
267.	Cheilinus oxycephalus Bleeker, 1853	●	O	O	O
268.	Cheilinus trilobatus Lacépède, 1801	●	●	●	O
269.	Cheilinus undulatus Rüppell, 1835	●	O	●	O
270.	Cheilio inermis (Forsskål, 1775)	●	●	●	O
271.	Choerodon gymnogenys (Günther, 1867)	O	●	O	O
272.	Cirrhilabrus exquisitus Smith, 1957	●	O	O	O
273.	Coris formosa (Bennett, 1834)	●	O	O	O
274.	Coris gaimard (Quoy and Gaimard, 1824)	●	O	O	O
275.	Cymolutes lecluse (Quoy & Gaimard, 1824)	●	O	O	O
276.	Epibulus insidiator (Pallas, 1770)	●	●	●	O
277.	Gomphosus caeruleus Lacépède, 1801	●	●	O	O
278.	Gomphosus varius Lacépède, 1802	●	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
279.	Halichoeres argus (Bloch & Schneider, 1801)	●	O	O	O
280.	Halichoeres dussumieri (Valenciennes, 1839)	O	O	N	●
281.	Halichoeres hortulans (Lacépède, 1801)	●	●	N	O
282.	Halichoeres hyrtlii Bleeker, 1856	O	●	O	O
283.	Halichoeres kawarin (Bleeker, 1852)	●	O	O	O
284.	Halichoeres leucurus (Walbaum, 1792)	O	O	●	O
285.	Halichoeres leparensis (Bleeker, 1852)	O	●	O	O
286.	Halichoeres marginatus Rüppell, 1835	●	●	O	●
287.	Halichoeres nebulosus (Valenciennes, 1839)	N	O	O	O
288.	Halichoeres notopsis (Valenciennes, 1839)	●	●	O	O
289.	Halichoeres scapularis (Bennett, 1831)	●	●	O	O
290.	Hemigymnus fasciatus (Bloch, 1792)	●	O	O	O
291.	Hemigymnus melapterus (Bloch, 1791)	●	●	N	O
292.	Hologmnosus doliatus (Lacépède, 1801)	●	●	O	O
293.	Labroides bicolor Fowler and Bean, 1928	*	O	O	O
294.	Labroides dimidiatus (Valenciennes, 1839)	●	●	O	O
295.	Macropharyngodon meleagris (Valenciennes, 1839)	●	O	O	O
296.	Novaculichthys taeniourus (Lacépède, 1801)	●	O	O	O
297.	Pteragogus flagellifer (Valenciennes, 1839)	●	O	N	O
298.	Stethojulis albovittata (Bonnaterre, 1788)	●	O	O	O
299.	Stethojulis interrupta (Bleeker, 1851)	●	O	O	O
300.	Stethojulis strigiventer (Bennett, 1832)	●	O	O	O
301.	Thalassoma amblycephalum (Bleeker, 1856)	●	O	O	O
302.	Thalassoma hardwicki (Bennett, 1828)	●	●	O	O
303.	Thalassoma herbraicum (Lacépède, 1801)	N	●	O	O
304.	Thalassoma janseni (Bleeker, 1856)	●	●	O	O
305.	Thalassoma lunare (Linnaeus, 1758)	●	●	O	O
306.	Thalassoma purpureum (Forsskål, 1775)	●	O	O	O
307.	Thalassoma quinquevittatum (Lay & Bennet, 1839)	●	●	O	O
308.	Thalassoma umbrostigma (Rüppell, 1835)	●	O	O	O
309.	Xyrichthys pavo Valenciennes, 1840	●	O	O	O
310.	Xyrichthys pentadactylus (Linnaeus, 1758)	O	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
	SCARIDAE				
311.	Calotomus spinidens (Quoy & Gaimard, 1824)	●	O	O	O
312.	Calotomus viridescens (Rüppell, 1828)	O	●	O	O
313.	Hipposcarus harid (Forsskål, 1775)	●	●	O	O
314.	Leptoscarus vaigiensis (Quoy & Gaimard, 1824)	●	●	●	O
315.	Scarus enneacanthus Lacépède, 1802	●	●	O	O
316.	Scarus frenatus Lacépède, 1802	●	O	O	O
317.	Scarus ghobban Rüppell, 1775	●	●	●	O
318.	Scarus globiceps Valenciennes, 1840	O	●	O	O
319.	Scarus niger Forsskål, 1775	●	O	O	O
320.	Scarus prasiognathos Valenciennes, 1840	●	●	O	O
321.	Scarus psittacus Forsskål, 1775	●	●	O	O
322.	Scarus rubroviolaceus Bleeker, 1847	*	O	O	O
323.	Scarus scaber Valenciennes, 1840	●	O	●	O
324.	Scarus sordidus Forsskål, 1775	●	O	O	O
	CIRRHITIDAE				
325.	Cirrhitus pinnulatus Schneider, 1801	●	O	O	O
326.	Paracirrhites forsteri Schneider, 1801	●	●	O	O
	MUGILOIDIDAE				
327.	Parapercis cephalopunctata (Seale, 1901)	●	●	O	O
328.	Parapercis hexophthalma (Ehrenberg, 1829)	●	●	O	O
329.	Parapercis pulchella (Temminck & Schlegel, 1843)	O	O	O	●
330.	Parapercis xanthozona (Bleeker, 1849)	O	●	O	O
	SIGANIDAE				
331.	Siganus argenteus (Quoy & Gaimard, 1825)	●	O	O	O
332.	Siganus canaliculatus (Mungo Park, 1797)	O	●	●	●
333.	Siganus javus (Linnaeus, 1766)	●	●	●	O
334.	Siganus luridus (Rüppell, 1828)	O	O	*	O
335.	Siganus spinus (Linnaeus, 1758)	O	●	O	O
336.	Siganus stellatus Forsskål, 1775	●	O	O	O
337.	Siganus vermiculatus (Valenciennes, 1835)	O	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
338.	Siganus virgatus (Valenciennes 1835)	O	●	O	O
	ZANCLIDAE				
339.	Zanclus canescens (Linnaeus, 1758)	●	O	●	O
	ACANTHURIDAE				
340.	Acanthurus bleekeri Günther, 1861	●	●	●	O
341.	Acanthurus dussumieri Valenciennes, 1835	●	●	●	O
342.	Acanthurus leucosternon Bennett, 1832	●	●	●	O
343.	Acanthurus lineatus (Linnaeus, 1758)	●	●	●	O
344.	Acanthurus mata (Cuvier, 1829)	●	O	O	O
345.	Acanthurus nigricans (Linnaeus, 1758)	●	O	O	O
346.	Acanthurus nigricauda Duncker & Mohr, 1929	●	O	●	O
347.	Acanthurus philippinus Herre, 1927	●	●	O	O
348.	Acanthurus tennentii (Günther, 1861)	●	O	O	O
349.	Acanthurus triostegus (Linnaeus, 1758)	●	●	●	O
350.	Acanthurus xanthopterus Valenciennes, 1835	●	●	●	O
351.	Ctenochaetus strigosus (Bennett, 1828)	●	●	●	O
352.	Naso brachycentron (Valenciennes 1835)	●	O	O	O
353.	Naso brevirostris (Valenciennes, 1835)	●	O	●	O
354.	Naso lituratus (Schneider, 1801)	●	O	O	O
355.	Naso tuberosus Lacépède, 1802	●	O	●	O
356.	Naso unicornis (Forsskål, 1775)	●	●	O	O
357.	Naso vlamingii (Valenciennes , 1835)	●	O	O	O
358.	Paracanthurus hepatus (Linnaeus, 1766)	●	O	O	O
359.	Zebrasoma veliferum (Bloch, 1797)	●	O	O	O
	SCORPAENIDAE				
360.	Ablabys macracanthus (Bleeker, 1852)	O	●	O	O
361.	Ablabys taenianotus (Cuvier, 1829)	O	●	O	O
362.	Dendrochirus brachypterus (Cuvier, 1829)	●	O	O	O
363.	Dendrochirus zebra (Quoy & Gaimard, 1829)	●	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
364.	Gymnapistes dracaena (Cuvier, 1824)	O	O	●	O
365.	Gymnapistes niger (Cuvier, 1829)	O	●	O	O
366.	Parascorpaena bleekeri (Day, 1878)	O	●	O	O
367.	Parascorpaena picta (Cuvier, 1829)	●	●	O	O
368.	Pterois antennata (Bloch, 1787)	●	O	O	O
369.	Pterois miles (Bennett, 1828)	●	O	●	O
370.	Pterois radiata Cuvier, 1829	●	●	O	O
371.	Pterois russellii Bennett, 1831	O	O	●	●
372.	Pterois volitans (Linnaeus, 1758)	●	●	O	O
373.	Scorpaenodes guamensis Quoy & Gaimard, 1824	●	●	O	O
374.	Scorpaenodes parvipinnis Garrett, 1863)	●	O	O	O
375.	Scorpaenopsis cirrhosa (Thunberg, 1793	●	●	O	O
376.	Scorpaenopsis gibbosa (Bloch & Schneider, 1801)	●	O	O	O
377.	Scorpaenopsis venosa Cuvier, 1829	O	●	O	O
378.	Sebastapistes nuchalis (Günther, 1871)	●	O	O	O
379.	Sebastapistes oglinus (Smith, 1949)	●	O	O	O
380.	Sebastapistes strongia (Cuvier, 1829)	●	●	O	O
381.	Setarches guentheri Johnson, 1862	O	●	O	O
382.	Synanceia verrucosa Bloch & Schneider, 1801	●	O	O	O
383.	Taenianotus triacanthus Lacepede, 1802	●	O	O	O
	BALISTIDAE				
384.	Abalistes stellatus (Lacépède, 1798)	O	●	O	O
385.	Balistapus undulatus (Mungo Park, 1797)	●	●	O	O
386.	Balistes vetula Linnaeus, 1758	O	O	●	O
387.	Balistoides conspiculum (Bloch & Schneider, 1801)	●	O	O	O
388.	Balistoides viridescens (Bloch & Schneider, 1801)	●	●	N	O
389.	Canthedermis maculatus (Bloch, 1786)	●	O	O	O
390.	Melichthys indicus Randall & Klausewitz, 1973	●	●	O	O
391.	Odonus niger (Rüppell, 1836)	●	O	●	O
392.	Pseudobalistes flavimarginatus (Rüppel, 1829)	●	●	●	O
393.	Rhinecanthus aculeatus (Linnaeus, 1758)	●	●	O	O

(1)	(2)	(3)	(4)	(5)	(6)
394.	Rhinecanthus rectangulus (Bloch & Schneider, 1801)	●	O	O	O
395.	Sufflamen bursa (Bloch & Schneider, 1801)	N	O	O	O
396.	Sufflamen chrysopterus (Bloch & Schneider, 1801)	●	●	O	O
397.	Sufflamen fraenatus (Bloch & Schneider, 1801)	N	●	●	O
	MONACANTHIDAE				
398.	Acanthus barbatus Gray, 1831	●	●	O	O
399.	Aluterus monoceros (Linnaeus, 1758)	O	●	O	O
400.	Aluterus scriptus (Osbeck, 1765)	●	●	●	O
401.	Cantherhines pardalis (Rüppell, 1837)	●	O	O	●
402.	Oxymonacanthus longirostris (Bloch & Schneider, 1801)	●	O	O	O
403.	Paraluteres prionurus (Bleeker, 1851)	●	O	O	O
404.	Paramonacanthus choirocephalus (Bleeker, 1852)	●	O	●	●
405.	Paramonacanthus barnardi Fraser - Brunner, 1941	●	O	O	O
406.	Stephanolepis diaspros Fraser - Brunner, 1941	O	O	N	●
	OSTRACIIDAE				
407.	Lactoria cornuta (Linnaeus, 1758)	●	●	O	O
408.	Ostracion meleagris Shaw, 1796	●	O	O	O
409.	Ostracion cubicus Linnaeus, 1758	●	O	O	O
410.	Rhynchostracion nasus (Bloch, 1785)	●	●	O	O
411.	Tetrosomus gibbosus (Linnaeus, 1758)	O	●	O	●
	TETRAODONTIDAE				
412.	Arothron immaculatus (Bloch & Schneider, 1801)	●	●	O	●
413.	Arothron meleagris (Bloch & Schneider, 1801)	●	●	O	O
414.	Arothron nigropunctatus (Bloch & Schneider, 1801)	●	●	O	O
415.	Arothron stellatus (Bloch & Schneider, 1801)	●	O	O	●
416.	Canthigaster amboinensis (Bleeker, 1865)	●	O	O	O
417.	Canthigaster bennetti (Bleeker, 1854)	●	O	O	O
418.	Canthigaster valentini (Bleeker, 1853)	●	●	O	O
419.	Canthigaster margaritatus (Rüppell, 1828)	●	O	O	O
420.	Chelonodon patoca (Hamilton, Buchanan 1822)	O	●	●	O
421.	Lagocephalus lunaris (Bloch & Schneider, 1801)	O	O	O	●

REMARKS

Fish families found on tropical coral reefs have a virtually worldwide distribution on both coral and non-coral, rocky substrata (Thresher, 1991). The work on coral reef fishes of India was mainly restricted to the Lakshadweep group of islands as evidenced by several publications by Jones and Kumaran (1964, 1966, 1967, 1968a, 1968b), 1970a, 1970b) culminating in their 'Fishes of the Laccadive Archipelago' (Jones and Kumaran, 1980) and by the absence of similar work from other coral reef ecosystems, consequently one has to perforce depend upon older publications or compilations of Day (1878) and Herre (1938) for Andaman and Nicobar Islands and Murty (1969) for the Gulf of Mannar and Palk Bay region. Even such accounts are not available for the Gulf of Kutch region because the region has received very little ichthyological activity in the past and intensification of efforts now is not likely to yield any significant collections due to a dead coral reef ecosystem. Deterioration of the environment in Kutch was also reported by Pillai et al. (1980) and Patel (1985).

Fishelson (1980) stated that, greater the variety of habitats in a region, greater is the number of users. In the present study, the Gulf of Kutch region recorded only five distinct sub-habitats, all of which were devoid of luxuriant coral growth. The fish specimens in the available collections of the Aquatic Science Research Institute, Okha, Gujarat show typical coral associated species (Chaetodontidae) which indicate the existance of a healthy coral reef ecosystem in the past. It is evident that the varying intensity of collection efforts from different regions in the country contributed to the highly variable estimates of fish species from the four regions.

It may be stated that the present picture of reef fish distribution resulted from varying regional efforts involved in collection and documentation of fishes from the coral reef regions. Lakshadweep has received greater efforts in fish species documentation. The reefs of Andaman Islands and Gulf of Mannar may account for a wider variety of fish species. Comparatively fewer species were found in Gulf of Kutch. A few probable factors determining the reef fish distribution are nature of reef formation, habitat/topographic complexity, dispersal by currents and trophic features. Generalizations about the composition and dynamics of the diverse reef fish assemblages in the four regions is not attempted in this account for want of complete and reliable data.

CHAPTER III

CORAL REEF FISH COMMUNITY ORGANISATION ON KAVARATTI ATOLL

CORAL REEF FISH COMMUNITY ORGANISATION ON KAVARATTI ATOLL

INTRODUCTION

Discrete populations, small breeding pools, sedentary and non migratory nature and association with specific habitats are striking characters of coral reef fishes. A variety of habitats found in coral reef areas may be rich or poor in species in each habitat or between differing habitats, supporting markedly different fish communities of which some may be cosmopolitan. Dependence on a particular food item, behavioural interactions and depths across reefs are other factors known to limit reef fish distribution.

Although the study of the ecology of reef fishes is relatively recent, it is developing rapidly, with many workers at present active in the tropical western Atlantic and Caribbean, the Gulf of California, several centres in the vast Indo-West Pacific, and in the Red Sea (Sale, 1980). There is an overall paucity of knowledge on this subject from the Indian region, leaving gaps in the works or reviews of workers who attempted to summarise a global picture on reef fish community organisation.

With the availability of limited facilities, the present investigation will form a basis on coral reef fish community organisation

which opens up understanding on patterns of neumerical densities, species richness, species composition and their occurrences on each of the five sub-habitats classified on Kavaratti atoll and the reef slope in general.

REVIEW OF LITERATURE

Community structure

The community structure of reef fishes has not been studied on Indian reefs and therefore no literature pertinent to the subject from the country is available. Few studies related to reef fish ecology are those from Minicoy atoll on Chromis caeruleus (Madan Mohan et al., 1986), Abudefduf glaucus (Pillai and Madan Mohan, 1990), massive recruitment of Ctenochaetus strigosus (Pillai et al., 1984), biology, ecology and coexistance of pomacentrids (Pillai et al., 1985, 1986, 1987) and ichthyofauna of the intertidal reef flats (Pillai et al., 1992). Vijay Anand and Varghese (1990) gave an account of seven important families of ornamental fishes of Lakshadweep that includes aspects of feeding, behaviour, habitats and reproduction. Suresh (1991) visually ennumerated the abundance of coral reef fishes on four atolls, namely, Kavaratti, Kalpeni, Amini and Kadmat and indicated their occurrence as abundant, common and rare.

Vast literature exists on the community structure of reef fishes. Though full access to such literature is limited, pertinent studies are reviewed in the following account.

In comparing the structure of two western Atlantic reef-fish assemblages, Alevizon and Brooks (1975) found that Key Largo reefs contained a greater number of species, diversity and evenness compared to that of the Venezuelan reefs. With regard to sociobiology of four Puerto Rican parrotfishes, Barlow (1975) observed that different species hold large territories encompassing home ranges and exhibit roving feeding aggregations. Ehrlich (1975) studied the population biology of coral reef fishes. In the possible determinants of community structure for coral reef fishes in an experimental habitat Sale and Dybdahl (1975) found no evidence that fishes occupying the habitats partitioned the habitat on the basis of precise micro-habitat requirements that normally cause particular species to occur consistently in particular habitats and a similar study was also conducted on isolated coral heads at lagoon and reef slope sites (Sale and Dybdahl, 1978). Patterns of community structure in fishes was summarised by Helfman (1978). The significant increase in species per census at Florida as compared to high Australian reef fish species packing is related to the "Intermediate disturbance hypothesis" where the disturbance is periodic winter (Bohnsack and Talbot, 1980). Emery and Thresher (1980) in their studies on the biology of damsel fishes, dealt with aspects of the structure of assemblages. The patch reef assemblages exhibited significant change in structure through a 28 month period and appeared to have low stability (Sale, 1980 b), while the dynamics of the pomacentrid community in particular on small patch reefs was studied by Williams (1980). Studies on faunal similarity of coral reef fishes, micro-habitats trophic analyses were conducted by Anderson et al. (1981). Distribution

and abundance of herbivorous grazing fishes on three locations on the continental shelf (inshore, midshelf and outershelf) on the Great Barrier Reef were studied through visual census by Russ (1984 a).

Reef fish assemblages are loosely structured species groupings and lack high degree of stability anticipated by ecologists on theoretical groups (Sale, 1982). Patterns of settlement of new juvenile fish from the pelagic phase plays a major role in determining the variable structure of reef fish assemblages (Baker et al., 1983). The coral reef fish community in the shallow waters of Nuweiba, Gulf of Aqaba was analysed on different reef zones by Ben-Tuvia et al. (1983). In the estimation of juvenile and adult scarids, Choat (1983) found significant differences within reef areas of same depth stratum. Schools of juvenile haemilid fish migrate onto seagrass beds to feed at night and rest among coral heads by day (Meyer et al., 1983). A greater emphasis was laid on settlement by juveniles from pelagic stages as compared to the physical structure of the reef in determining the variable structure of fish assemblages (Sale, 1983). Species richness and community predictability was studied by Shulman (1983). Possible mechanisms causing and maintaining the differences in community structure across the continental shelf of the Great Barrier Reef were discussed by Williams and Hatcher (1983). Migration of coral reef fishes is attributed to three factors, namely, life history, spawning seasons and diel patterns (Ogden and Quinn, 1984). In a possible relation between community structure and reef structure, Sale and Douglas (1984) stated that species composition varied through time and structural attributes of the reef (other than size) are of little value in predicting fish assemblages. Alevizon et al.

(1985) found community structure to be significantly more similar at different sites within zones than among zones. Analysing interactions amongst herbivorous fishes, Choat and Bellwood (1985) observed Acanthurus lineatus to be aggressive towards other herbivores and was strongly site-attached. Findley and Findley (1985) found that species richness and individual abundance of butterfly fishes increased with coral density. Marked variations and changes in the composition of herbivore guild was observed with regard to acanthurids and scarids across reef habitats. Russ (1985) studied the effects of protective management of coral reef fishes in the central Philippines. Shulman (1985) made observations on intra-and interspecific aggressive interactions among fishes living in the rubble/sand coral reef habitat at St. Croix U.S. Virgin Islands. Habitat structure had little effect on fish communities during day but was important at night due to sheltering preferences (Walsh, 1985). In a study on fish community structure on French Polynesian coral reefs, possible explanations for a variable pattern in abundance, richness and composition of fish species on spatial scales were discussed by Galzin (1987 a) and temporal scales by Galzin (1987 b). Characteristics of fish communities on coral reef and potentially interacting shallow habitats in tropical oceans of the world was dealt by Parrish (1987). Hourigan (1988) observed that large butterfly fishes require a large foraging area. Harmelin-Vivien (1989) compared the Indo-Pacific reef fish community structure. Comparison between communities of the reef flat, reef edge and pelagic system in the Flores Sea reef environment was made by Martosewojo (1989), while the

chaetodontid species composition, distribution and abundance in the region was given by Adrim and Hutomo (1989). Studies on fish communities of shallow water habitats and their interactions in tropical oceanic regions were conducted by Parrish (1989). Coles and Tarr (1990) observed greater number of species and individuals at greater depths and discussed seasonal variations in reef fish assemblages in the western Arabian Gulf.

Ecology and distribution

Bardach (1958) made observations on habitats and movements of fishes belonging to the families, Chaetodontidae, Acanthuridae, Pomacentridae, Scaridae, Serranidae and Haemulidae. Hiatt and Strasburg (1960) qualitatively documented the differences in species composition, characteristic of the fish fauna found in different reef habitats of the Marshall and Marianas Islands. Food habits and habitats frequented by groupers and snappers of the Society Islands were investigated preliminary to the introduction into Hawaiian waters from French Oceania by Randall and Brock (1960). The centres of abundance, ecological ranges and other requirements of six species of Hawaiian cardinal fishes were discussed by Chave (1978). Patterns observed in the structure of reef fish communities were described by Sale (1980a) together with factors responsible for such structures, trophic relationships and certain aspects of their social organisation arising from behavioral interactions. Ecological studies on coral reef fishes have made immense strides and are contained in the book entitled 'Ecology of fishes on coral reefs edited by P.F. Sale (Ref: Sale 1991a, b).

Referring particularly to studies on the distribution/abundance of coral reef fishes, there have been numerous regional works like those on inshore fishes at Canton atoll (Grovhoug and Talbot, 1976), eastern Gulf of Mexico (Smith, 1976), outer slope of Tulear Reef (Harmelin-Vivien, 1977), Sundanese coral reefs (Vine and Vine, 1980; Edwards and Rosewell, 1981), Guam (Kock, 1982), Central Great Barrier Reef (Williams, 1982), outer slopes of Aldabra, Indian Ocean (Forster, 1984), Pulau salu, Singapore (Tay and Khoo, 1984) and basin and channel habitats in Florida Bay (Thayer and Chester, 1989).

The quantitative distribution of herbivorous reef fishes in the Gulf of Aqaba (Red Sea) was studied by Bouchon - Navaro and Harmelin - Vivien (1981). Harmelin - Vivien (1984) stated that the biomass of herbivourous fish (Acanthuridae and Scaridae) per surface unit is greater on the outer slope than in the lagoon. Herbivorous fishes (Acanthuridae, Scaridae and Siganidae) from the Central Great Barrier Reef occurred consistently in assemblages characteristic of several physiographic zones (Russ, 1984 b), while in studies on the levels of variability across the continental shelf, inshore assemblages were distinct from those on outer and mid-shelf reefs.

Emery (1973) compared the ecology and functional morphology of fourteen species of damselfishes at Aligator Reef, Florida Keys, and found that they were distributed from the shore line to over 45 m in depth and within the depth limits of each species, distribution was related to features of the environment on which the species depended for

feeding, reproduction or protection from predation. de Boer (1978), in his work, distinguished between different factors of reef complexity and tried to ascertain their influence on the distribution of Chromis cyanea. The ecology, social organisation, age structure and population stability of the three-spot damselfish was dealt by Williams (1978). With reference to distribution of planktivorous reef fish Kingsford (1989) suggested that hydrobiology may influence the composition and abundance of zooplankton which in turn influences the fish.

Other than major herbivorous and planktivorous fishes, chaetodontids have been widely studied. Shen (1973) conducted ecological and morphological studies of chaetodontid fishes from the waters around Taiwan and its adjacent Islands. Burgess (1978) studied the butterflyfishes of the world. Wood (1979) found the greatest number of butterflyfishes on shallow, actively growing reefs. A quantitative account on distribution of chaetodontid fishes on a fringing reef of the Jordanian coast (Gulf of Aqaba) was given by Bouchon - Navaro (1980), while a similar study on a reef of Moorea Island (French Polynesia) was conducted by Bouchon - Navaro (1981). Lindquist and Gilligan (1986) studied the distribution and relative abundance of butterflyfishes and angelfishes in Bahamas, while a similar study in the Flores sea was made by Adrim and Hutomo (1989). Findley and Findley (1989) described the circumtrophical patterns in butterflyfish communities. The spatial and temporal patterns of chaetodontid fishes at one Tree Reef, southern Great Barrier Reef were studied by Fowler (1990).

Habitat partitioning, resource sharing and overlap

Competition for shelter, food and mates among fishes is known to be intense in coral reefs. Detailed studies on habitats of fish and their influence on structuring communities are numerous. Few important examples of such studies are those on partitioning of reef slope by resident fishes (Bradbury and Goeden, 1974), habitat partitioning in damselfishes (Belk, 1975), niche separation of two damselfishes by aggression and differential microhabitat utilization (Ebersole, 1985), partitioning of food and space resources by chaetodontid fishes (Bouchon-Navaro, 1986), and resource partitioning in fish assemblages (Ross, 1986).

Habitat distribution and species diversity of chaetodontid and pomacentrid fishes near Bimini, Bahamas was studied by Clarke (1971). Few other studies on habitat are those on its utilization by a guild of damselfishes (Waldner, 1979), influence of habitat and behavioural interactions (Jones, 1984), relationship between habitat structure and fish fauna on New Zealand Reefs (Choat and Ayling, 1987) and habitat complexity and coral reef fish diversity and abundance on Red Sea fringing reefs (Roberts and Ormond, 1987), Substrate characteristics on coral reefs was found to positively influence the abundance and diversity of coral reef fish communities (Luckhurst and Luckhurst, 1978a ; Carpenter et al., 1981; Bell and Galzin, 1984; Hixon and Brostoff, 1985). Aspects of coral selection in two pomacentrid fish species were studied by Waldner (1983). Microtopography and the organisation of two

assemblages of coral reef fishes in the West Indies was described by Kaufman and Ebersole (1984). Phillips and Perez-Cruet (1984) observed an increase in fish sizes with increase in habitat complexity. At St. Croix, U.S. Virgin Islands, Shulman (1984) assessed the potential effects of food and shelter availability on recruitment and early surviorship of coral reef fishes. Chaetodon trifasciatus was studied on the southern Great Barrier Reef for its spacing patterns by Sutton (1985). Robertson and Gaines (1986) investigated patterns of habitat use arising due to interference competition for food. Temporal and spatial variations in an island fish fauna was dealt by Choat et al. (1988). Naesje et al., (1991) studied habitat switch and niche overlap in coregonid fishes.

Seagrasses as fish habitats

From various studies conducted on seagrasses in relation to fish fauna, it is possible to identify major characteristics of fish assemblages associated with seagrasses. Studies concerning community structure of fishes on seagrasses include those on structural analysis of fish communities on Zostera marina beds (Adams, 1976), ichthyofaunal relationships on Caribbean seagrass beds (Ogden, 1976; Ogden and Zieman, 1977; Weinstein and Heck, 1979), role of macrophyte biomass and species composition on distribution of fishes (Stoner, 1983), structural differences in the fish communities of Zostera capricorni and Posidona australis, seagrass meadows in Botany Bay, New South Wales (Middleton et al., 1984), influence of plant structure and prey characteristics on predator-prey relationships (Orth et al., 1984),

effects on fish and decapods due to variation in seagrass height and density (Bell and Westoby, 1986 a), effects of local changes in leaf height and density to fish and decapods (Bell and Westoby, 1986 c) and location of seagrass beds in estuaries and effects on fish and decapods (Bell et al., 1988), spatial distribution and trends in abundance of fishes in seagrass meadows on Florida Bay mudbanks (Sogard et al., 1989), differences in fish essemblages associated with Zostera capricorni and bare sand (Ferrel and Bell, 1991), fish assemblages in natural versus well established recolonized seagrass meadows (Brown-Peterson et al., 1993) and fish communities of a shallow tropical lagoon in Belize, Central America (Sedberry and Carter, 1993).

Den Hartog (1979) identified 19 groups of fauna and flora associated with seagrasses some of which are of interest for the fish community. A review of ecological studies on seagrass fish communities with reference to recent studies in Australia was given by Pollard (1984). Effects of the proximity of seagrasses or mangroves to coral reefs and the abundance of reef fish was studied by Quinn and Kojis (1985). Few aspects of seagrass fish fauna were dealt by Sheppard et al. (1992).

Summarising various aspects of ecology of fish assemblages with seagrasses, Bell and Pollard (1989) dealt with diversity and abundance, residence time, seagrasses as nurseries and food sources for fish, distribution of fish species and effects of proximity with other habitats.

Territorality and co-existance

Space requirements usually relate to the individuals' territory or home range which obviously includes more specific resources such as food supply or shelter (Sale, 1991a). Interspecific territorality in Pomacentrus flavicauda was described by Low (1971), Dascyllus aruanus is a territorial damselfish and exhibits a limited home range, usually centered on a single coral colony (Sale, 1971). Depending on the behavour and ecological adaptations of fish species, the duration of residence on reefs is highly variable (Reese, 1973). Nursall (1974) described territorial and behavioural attributes of Acanthurus lineatus at Heron Island, Queensland. The adaptive significance of interspecific territoriality in the reef fish Eupomacentrus leucostictus was invesigated by Ebersole (1977), various resources that the territorial Caribbean damselfish, Eupomacentrus planiforms derives from a coral mass, were studied by Robertson et al., (1981). Shpigel (1982) dealt with mechanisms involved in niche overlap between Dascyllus aruanus and D. marginatus, while interacts between recruits and resident D. aruanus were observed by Sweatman (1983). Roberts (1985) studied aspects of resource sharing in territorial herbivorous reef fishes.

Dale (1978) gave examples of coral reef fish that co-exist with apparent spatial resource partitioning and used a financial analogy to explain the mechanisms. Sale (1978) described how coral reef fish overcome the limited and patchy supply of living space by coexistence. Brief descriptions on various associations among fishes with anemones,

corals etc. were described in a popular article by Wallin (1978). In a study on co-existance of some coral reef fishes from the western Indian Ocean, Robertson and Polunin (1981) dealt with symbiotic sharing of feeding territories and algal food, while from a Caribbean coral reef, Robertson (1984) investigated cohabitation of competing territorial damselfishes. Draud et al. (1990) studied codefence of territory by two species of coral reef fishes.

Other topics of interest

Behaviour and distribution are completely different between night and day for almost all reef fish species (Goldman and Talbot, 1976). Studies on diurnal-nocturnal activity of fishes in the Gulf of California (Hobson, 1965), Hawiian reef fishes (Hobson, 1972), Bahamian coral reef fishes (Colton and Alevizon, 1978), and diurnal space utilisation (Luckhurst and Luckhurst, 1978) are some examples.

With regard to stability of fish assemblages, Molles (1978) and Talbot et al. (1978) have showed marked seasonal variation in the rates of recruitment in number of fishes and number of species on artificial reefs and discussed about their investigations on the coral reef fish communities and their stability as high diversity systems, while aspects on stability and structure of a fish community on patch reefs in Hawaii were observed by Brock et al. (1979). Equality in distribution of fishes from French Polynesian reefs was studied by Galzin (1985).

Communities of fish on coral reefs are widely recognised as diverse compared with those in other habitats (Emery, 1978). Some studies on fish species diversity were those on Virgin Islands (Risk, 1972), Tulear reef, Madagascar (Harmelin-Vivien, 1977) Enewetak atoll (Thresher and Colin, 1986) maintenance of high diversity in coral reef fish communities (Sale, 1977), diversity on model artificial and natural patch reefs (Molles, 1978), comparison of similarity and diversity between tropical Western Atlantic (Virgin Islands) and tropical central Pacific (Marshall Islands) patch reefs (Gladfelter et al., 1980) and Gulf of California rocky-shore fish community (Gilligan, 1980).

Behaviour in relation to feeding habits and requirement of shelter sites influence the distribution of coral reef fishes. Bakus (1966) described some relationships of fishes to benthic organisms on coral reefs. Reese (1978) studied space related behaviours in aquatic animals. The interrelationship between group behaviour and other biological characteristics were investigated by Radakov (1979). In a study on behavioural ecology, Robertson et al. (1979) studied three species of acanthurids with regard to feeding strategies, social and mating systems. Robertson and Sheldon (1979) gave an account on competitive interactions and availability of sleeping sites for a diurnal coral reef fish. Some other studies on behaviour are on two sympatric wrasses of the coast of Florida (Thresher, 1977), activity patterns of Halichoeres poecilopterus under artificial conditions (Kabasawa, 1982), biotopic variability of behaviour in coral reef fish (Mochek and Val' Des - Mun'oz, 1984),

gathering behaviour on the natural reef (Yasunaga et al., 1985), and social behaviour, foraging effeciency and habitat utilization in a group of herbivorous fishes (Reinthal and Lewis, 1986).

A limited amount of information has been obtained on the effects of disturbances to the reef habitat on the resident fishes (Sale, 1991). Some important studies are those on Florida Keys following a hypothermal fish kill (Bhonsack, 1983), effects of hurricane 'Allen' on reef fish assemblages near Discovery Bay, Jamaica (Kaufman 1983), cyclonic storm at Lizard Island (Lassig, 1983), stability of coral reef fish community following a catastrophic storm (Walsh, 1983), changes in fish communities due to desturction of hermatypic corals (Sano et al., 1984 a), impact of coral degradation on chaetodontid fish population (Bouchon-Navaro et al., 1985), hurricane effects on an aquarium fish fishery at Hawaii (Pfeffer and Tribble, 1985), variation in fish abundance due to Acanthaster plancii infestation (Williams, 1986) and impact of hurricane on fish community structure on fringing reefs of Reunion Island Letrouner et al., 1993).

MATERIAL AND METHODS

Fish species ennumeration and their distribution among distinct physiography zones (referred to as sub-habitats in the present investigation) was studied at Kavaratti atoll using the visual census technique - which is frequently used for determining the abundance and diversity of fish present in an area.

Five sub-habitats designated as - Live coral (consisting of extensive lagoonal patch reefs built exclusively by live coral of the genus Acropora); Massive coral (predominated by coral of the genus Porites); Rubble (consisting of dead coral fragments and other storm material with encrusting coralline algae and a wide variety of concealed invertebrates); sand flats (barren sandy areas occassionally with some rubble or seagrasses) and seagrass beds (consisting of seagrasses belonging to the genera Thalassia and Cymodocea). The outer reef slope (on the windward slope of the atoll) was not treated at par with other sub-habitats as this region is composed by a combination of various physiographic reef characters and does not maintain homogenity as seen in the sub-habitats. Further, the sampling strategy used for the reef slope had to be varied for practical purpose. Details are given in Chapter I.

The visual census techniques include a considerable variety of procedures (reviewed by Sale, 1980). This method is non-destructive and permits repeated sampling of an area without physical disturbances to the populations present. In the present investigation due to limited facilities, a combination of/or modifications of existing methods have been used to suit the sub-habitats. Belt transects of 30 m length (Grovhoug and Talbot, 1976) were used to record all visible fish species and numbers from 2 m on either sides of a pre-laid line. Transect width was estimated visually (Roberts and Ormond, 1987). Due to shallow depths and absence of SCUBA facility, the fish were observed using a mask and snorkel apparatus (Sale, 1974; Grovhoug and Talbot,

1976; Bouchon-Navaro and Harmelin-Vivien, 1981; Hutomo and Adrim, 1986; Adrim and Hutomo, 1989; Bouchon-Navaro and Bouchon, 1989) with three intervals to record the observations. The approximate area covered by a single census unit is 120 sq. m. for each subhabitat. Censuses were conducted fortnightly for 18 months; this resulted in 27 censuses for each sub-habitat. Censuses were not conducted when rough weather conditions prevailed. The period of study was from January 1991 to June 1992.

Fish species from the outer reef slope were recorded using a 100 m belt transect running parallel to the reef crest, the total width of the transect being approximately 6 m visually estimated (Roberts and Ormond, 1987). Depths in the region varied between 4 to 6 m. The area of each census was approximately 600 m^2. Belt transect of a similar dimension was used by Adrim and Hutomo (1989) where they conducted censuses along a 50 m transect line parallel to the reef edge or shore line counting fishes from 5 m on either side of the line (total width - 10 m) by snorkel and skin-diving. The censused area was approximately 500 m^2. In the present investigation the length of the transect was marked on the adjacent reef crest using flag posts. The end points of the transect in water were permanently marked using two small anchored floats. A glass bottomed boat driven slowly along the transect (aligning with reef crest flags & floats in the water) by an assistant was used to record visible fish species continuously by the investigator. Use of the glass bottomed boat permitted easy counting and rapid recording. Sampling in this region was avoided during rough monsoon conditions thus resulting in 22 censuses from the reef slope.

The visual censusing techniques are commonly used to study coral reef fish populations and include a considerable variety of procedures that have both advantages and disadvantages. The principal drawbacks of the method are that they fail to take into account the fish species that are small and cryptic, nocturnal or rare in occurrence, and therefore are short of complete censuses (Sale, 1980a, 1983, 1991b). Users of visual censuses make a distinction between resident species which remain within the census site and more vagile species which enter and leave the census site either singly or in schools. In some cases, both classes are censused; in others vagile species are eliminated from consideration (Sale, 1980a). In the present investigation, vagile species encountered in large schools were eliminated (Risk, 1972) to avoid overemphasis of a particular group. While vagile species that occur singly were included, certain typical reef associated species like caesionids, juvenile and sub-adult scarids etc. which occur in schools were counted in 10's, 50's or 100's. In most cases, fish species were identified upto species level except those that were difficult to distinguish quickly underwater and such species were treated as single groups (Bouchon-Navaro and Harmelin - Vivien, 1981; Sale and Douglas, 1981).

As fish populations are mixed and highly mobile on a local basis, a large sampling variance is expected and thus a repetetion of samples is needed (Goldman and Talbot, 1976). Cryptic species are not seen and abundant species are often in-accurately counted. In addition, individuals which live at, but range away from the site may be absent at the time of the visit and other which are rarely present, or just

passing by, may be recorded (Sale and Douglas, 1981). To minimise the recognised tendency of census to underestimate the numbers of fish present, a combination of successive census results has been recommended (Russel et al., 1978) and has been used in the present investigation. Fish species counts that are likely to be influenced by environmental conditions, behavioural activities, secretive/cryptic nature were expected to be included in successive visual records. Further, several transient fishes which may not use a particular sub-habitat intensively are also likely to be included, resulting in building up lists of species (species composition) characteristic to the five sub-habitats and the reef slope.

Data collected from each census were grouped under two taxonomic scales, namely, (A) families and (B) species. These were tranformed into a data matrix for respective sub-habitats (Fig. 15) and the reef slope. Results obtained from the data matrix were used to study five aspects of the community organisation of coral reef fishes on the five sub-habitats and reef slope.

1. Community parameters: Results of all censuses were combined to obtain the information mentioned below:-

a. Families/species composition of the particular region listed in the order of frequency of occurrence
b. Frequency of occurrence
c. Total abundance
d. Percentage abundance
e. Shannon - Weiner diversity index (H')

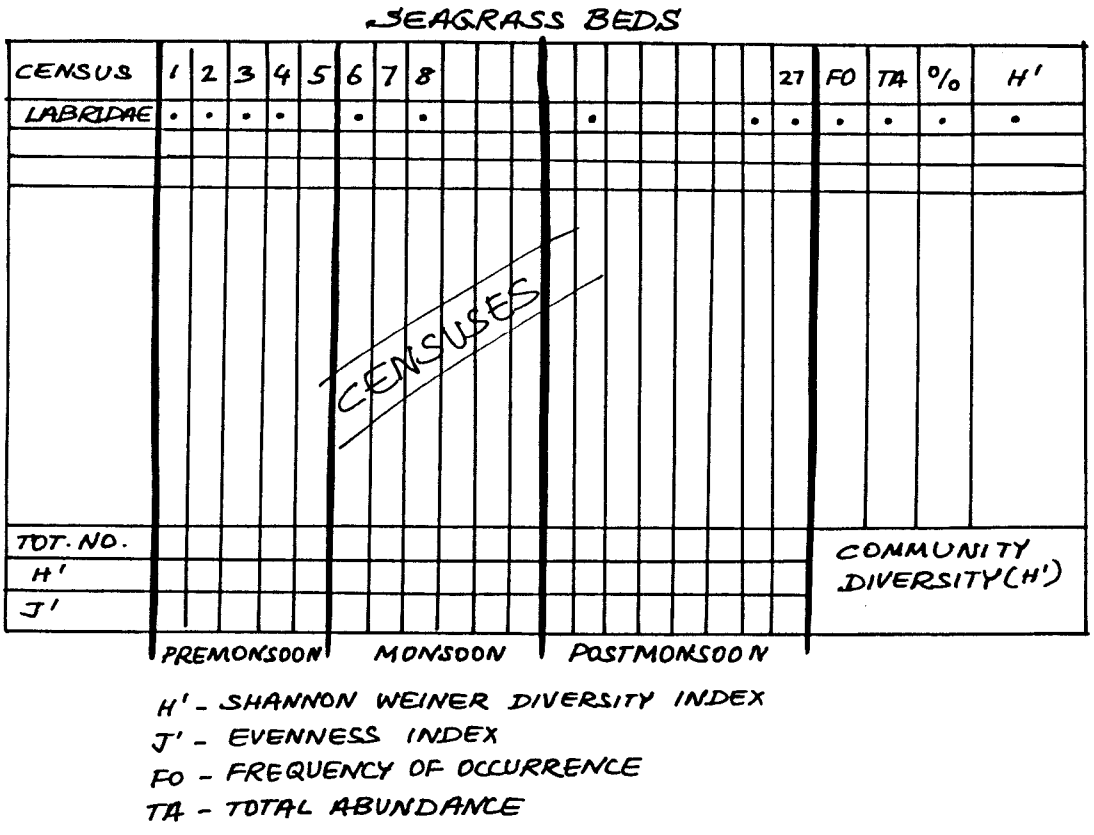


Figure 15. Data matrix for community organisation studies on sub-habitats.

2. Seasonal variation in community parameters: Results of all censuses were treated separately and were grouped into three distinct seasons prevailing in Lakshadweep region, namely, pre-monsoon (January to April), monsoon (May to August) and post-monsoon (September to December). These seasons have been classified based on a definite change in wind direction in the middle of May (South-westerly) and its subsequent termination in August and replacement by northeasterly winds. The information obtained is mentioned below:-

a. Total number of individuals (this parameter is expected to be the same for sections on families and species of a single census, but in certain samples a difference may be noted. This is due to elimination of families which include vagile schooling species in the family sections; and inclusion of solitary vagile species in the species section.

b. Total number of families/species.

c. Shannon - Weiner diversity index (H')

d. Evenness index (J')

3. Distribution of species: Complete lists of families/species were developed based on the data obtained from the five sub-habitats and are listed in the order of frequency of occurrence to study the distribution of fish species. Total frequency of occurrence and total abudance were obtained by combining values of the same from each sub-habitat. Percentage abundance of each family/species on the five sub-habitats, diversity (H') and evenness (J') indices were also computed to indicate

patterns of distribution among various sub-habitats. Reef slope region has not been considered for comparison owing to variation in sampling procedure and difference in physiographic character when compared to the homogenous character of the sub-habitats.

4. Presence or absence of species/families: The representation of a particular family or species on the five sub-habitats and the reef slope is pictorially depicted.

5. Community diversity: Based on total abundance estimates, the community diversity parameter for each sub-habitat and the reef slope was calculated for comparisons. However, direct comparisons between the five sub-habitats and the reef slope were not possible due to variation in sampling design.

The Shannon-Weiner species diversity index, H' (Shannon and Weiner, 1949) has been used widely in ecological studies as a measure that reflects both the number of categories or kinds of elements (richness) and the equality of distribution of elements among these categories (evenness). This index has also been used in various studies on fishes (Clarke, 1977; Molles, 1978; Rabenold, 1978; Bouchon-Navaro, 1986; Roberts and Ormond, 1987; Bakus et al., 1989; Sano, 1989) but is also known to have mathematical and theoretical shortcomings which were discussed by Peet (1974), May (1975, 1976) and Pielou (1975). In the present investigation the Shannon-Weiner diversity index (H') has been used only as a summary statistic that weighs moderately represented

catagories on a 0 to 5 scale, increasing in value with greater evenness as well as with greater richness. If the elements in a particular catagory (number of individuals in a particular family/species) are in proportions fi, the quantity

$$H' = - \sum (fi. \log_2 fi)$$

where fi = Ni/N is the proportion of the total number of individuals (N) belonging to the i th category (Ni). H' calculated for the community parameters on the sub-habitats and reef slope are from a set of samples accumulated from the same community over a large time domain. This includes heterogenities and gradients of ecological factors, thus eliminating bias and approaching close to reality (Frontier, 1985). Further, the calculation of diversity (H') based on taxonomic units other than species seems justifiable. Taxonomic classes like families or genera having more or less homogenous biology may represent a type of solution to the problem of occupation of the ecological space (Frontier, 1985).

The evenness index of Pielou (1966) was used to determine equitability of distribution of species or number of families in each census in the three seasons in Lakshadweep and between the sub-habitats. The index is given as,

$$J' = H' / \log_2 S$$

in which $\log_2 S$ is the maximum possible value of H'.

As already mentioned earlier, this chapter is given under two sections, namely, A. Families and B. Species. For convenience the observations also have been discussed seperately for the two sections.

RESULTS

A. FAMILIES

Community parameters on sub-habitats and reef slope

Live coral: Table 2 shows various community parameters of the 14 families recorded from the live coral region. Pomacentridae dominated (27 times) the sub-habitat followed by Chaetodontidae, Pomacanthidae and Labridae (Fig. 16A). Pomacentridae (1643 nos) accounted for greatest number of individuals comprising 62.10% of the total number of fishes recorded. This was followed by Pomacanthidae (348 nos) accounting for 13.16%. Chaetodontidae (245 nos) and Labridae (213 nos) accounted for 9.27 and 8.06% respectively (Fig. 16A). Serranidae, Balistidae and Scropaenidae were also common (14 to 17 times of the 27 samplings) with counts ranging between 34 and 63 individuals accounting for percentages between 1.29 and 2.38. Cirrhitidae, Muraenidae, Tetraodontidae and Ostraciidae were sporadic (4 to 7 times) registering percentages of less than one. Among the four families, Tetraodontidae (23 nos) and Cirrhitidae (21 nos) showed relatively higher densities while members in the other two

families appeared to be solitary. Acanthuridae, Fistulariidae and Grammistidae were represented only once.

Chaetodontidae indicated highest (4.71) diversity, followed by Pomacentridae (4.58), Pomacanthidae (4.55) and Labridae (4.33). Other families showed diversities between 2 and 4. Tetraodontidae (1.19) and Ostraciidae (1.50) recorded diversities below two. Acanthuridae, Fistulariidae and Grammistidae showed no diversity.

b. Massive coral: Table 3 shows various community parameters of the 26 families recorded from the massive coral region. Labridae occurred most frequently (27 times) accounting for highest abundance (906 nos) forming 25.44% while Scaridae closely compared with Labridae in recording 881 individuals forming 24.74% of fishes recorded (Fig. 16B), though it was encountered only 15 times. Chaetodontidae and Acanthuridae occurred 26 and 25 times respectively with the latter recording relatively higher counts (317 nos) composing 10.42% while Chaetodontidae recorded 275 individuals forming 7.72% (Fig. 16B). Pomacentridae (315 nos) was recorded 19 times forming 8.85%. Balistidae and Mullidae occurred 19 times followed by Serranidae (16 times) accounting for 70, 222 and 88 individuals forming 1.97, 6.22 and 2.47% respectively. Included in this category was Caesionidae with 200 counts though it appeared only twice. Haemulidae and Scorpaenidae were rare (9 and 8 times respectively) with counts

of 15 and 9 individuals, registering 0.42 and 0.25% respectively. Mugiloididae, Grammistidae, Ostraciidae, Monacanthidae, Muraenidae and Platacidae made rare appearances (2 and 5 times) with solitary individuals mostly accounting for percentages between 0.06 to 0.08, except Mugiloididae (0.48%) where 17 specimens were recorded. Abundances of Holocentridae, Tetraodontidae and Zanclidae were similar (25 to 29 nos) occurring 7 times, forming percentages below one except in Apogonidae (53 nos) which registered 1.48%.

Families that appeared only once were Diodontidae, Malacanthidae, Fistulariidae and Pomacanthidae, with the latter two registering a relatively higher percentage of 0.34 and 0.50 as compared to 0.03 and 0.06% in Diodontidae and Malacanthidae.

Between-sample diversities followed the pattern of frequency of occurrence in Labridae (4.58), Chaetodontidae (4.48) and Acanthuridae (4.13), followed by Pomacentridae and Mullidae which showed diversities of 4.07 and 4.02. Balistidae, Serranidae, Scaridae and Haemulidae accounted for diversities between 3.06 to 3.92 while in others it was between 1.00 to 2.78. Muraenidae and Platacidae indicated low diversity (0.92 each) while Diodontidae, Fistulariidae, Malacanthidae and Pomacanthidae did not show diversity.

c. Rubble: Table 4 shows various community parameters of the 15 families recorded from the rubble zone. Pomacanthidae, Scaridae and Labridae were most conspicious families on rubble (Fig. 17 A). Labridae was observed on all 27 samplings, summing upto 576 individuals, comprising of 19.34% of total individuals recorded. Pomacentridae registered highest counts of 1069 individuals (35.90%). Balistidae was recorded frequently (23 times) but indicated a relatively low abundance (141 nos) and percentage (4.73). Scaridae with 620 individuals (20.82%) ranked next to Pomacentridae, occurring only 8 times. Commonly observed (16 to 17 times) was Acanthuridae (195 nos) and Mullidae (132 nos) with percentages of 6.55 and 4.43 respectively.

Chaetodontidae, Gobiidae, Muraenidae and Nemipteridae were incidental in occurrence (7 to 9 times). Gobiidae registered more counts (111 nos) followed by Chaetodontidae (32 nos) Nemipteridae (26 nos) and Muraenidae (11 nos) with 1.07, 0.88 and 0.37% respectively. Members of Plesiopidae, Fistulariidae, Haemulidae, Serranidae and Apogonidae were rare in occurrence (1 to 4 times) with percentages ranging between 0.10 to 1.04. Of the five rare families, Plesiopidae and Serranidae accounted for 31 and 91 individuals respectively.

Labridae, Pomacentridae and Balistidae had diversities above 4; Labridae ranking highest (4.80). Acanthuridae, Mullidae and

Gobiidae recorded 3.87, 3.72 and 3.11 respectively. Diversity in other families ranged between 1.40 and 2.82 except in Haemulidae (0.92). Apogonidae showed no diversity.

d. Sand flats: Table 5 shows various community parameters of the 17 families recorded on sand flats. Labridae, Mullidae, Scaridae and Acanthuridae were most conspicious on sand flats (Fig. 17 B). Labridae occurred 25 times with counts of 402 individuals (31.36%). Acanthuridae and Mullidae appeared 22 times with 178 and 252 individuals forming 13.88 and 19.66% respectively. In par with other counts was Scaridae (206 nos) forming 16.07% though it occurred only 5 times.

Mugiloididae commonly appeared (14 times) recording 51 individuals (3.98%). Polynemidae, Scorpaenidae, Theraponidae and Sphyraenidae were also common (7 to 9 times). Of these four families, Theraponidae recorded relatively higher counts of 36 individuals (2.81%) followed by Sphyraenidae (31 nos) Polynemidae (25 nos) and Scorpaenidae (16 nos) forming 2.40, 1.95 and 1.25% respectively. Mugilidae (26 nos) also accounted for 2.03%, though recorded only 5 times.

Fistulariidae and Kuhlidae rarely appeared (3 times) and of the two, Kuhlidae recorded 39 individuals (3.04%) while the former recorded 5 individuals (0.39%). Balistidae, Bothidae, Gobiidae and Ostraciidae appeared only once.

Only two families, Labridae (4.45) and Acanthuridae (4.14) showed a diversity above 4. This was followed by Mullidae with 3.73. Commonly occurring families registered values ranging between 2.01 to 2.86. Diodontidae, Mugilidae, Scaridae and Fistulariidae had diversities between 1.20 and 1.76, while the rest showed no diversity.

e. Seagrass beds: Table 6 shows various community parameters of 27 families recorded on seagrass beds. Scaridae, Labridae, Mullidae and Acanthuridae were most conspicious (Fig. 18 A).

Labridae was persistent in occurrence (27 times) recording 824 individuals (20.01%), followed by Acanthuridae (26 times) Mullidae (22 times) and Chaetodontidae (21 times) recording 346, 355 and 207 individuals with proportions of 8.40, 8.62 and 5.03% respectively. In terms of total abundance Scaridae (1752 nos) ranked first contributing to 42.55%, while it appeared only 18 times.

Two commonly occurring families were Monacanthidae (13 times) and Fistulariidae (11 times) with counts of 33 and 149 individuals with proportions of 0.80 and 3.62% respectively. Similar to counts registered by Fistulariidae was that of Kuhlidae with 143 individuals (3.47%) occurring only 3 times. Diodontidae, Scorpaenidae, Balistidae, Pomacentridae, Bothidae, Zanclidae, Tetraodontidae, Belonidae occurred intermittently

between 4 to 9 times. Of these the maximum counts belonged to Blenniidae (42 nos), Pomacentridae (40 nos) and Belonidae (38 nos) with percentages of 1.02, 0.97 and 0.92 respectively.

Ostraciidae, Polynemidae, Sphyraenidae, Apogonidae, Mugilidae and Mugiloididae were rare. Of these, maximum individuals belonged to Sphyraenidae (38 nos), Polynemidae (19 nos) and Apogonidae (14 nos) with percentages of 0.92, 0.46 and 0.34 respectively. Malacanthidae, Nemipteridae, Siganidae and Theraponidae were encountered only once with low percentages.

Diversities greater than 4.00 were recorded in five families, namely, Labridae (4.44), Acanthuridae (4.28), Mullidae and Scaridae (4.21 each) and Chaetodontidae (4.11). This was followed by Monacanthidae (3.42) and Fistulariidae (3.06). Diodontidae, Scorpaenidae, Balistidae, Pomacentridae, Bothidae, Zancilidae and Tetraodontidae registered diversity values between 2.33 and 2.90 while Belonidae, Blenniidae, Kuhlidae, Ostraciidae, Polynemidae and Sphyraenidae accounted for values between 1.05 and 1.62. Other families except Mugilidae (0.92) and Mugiloididae (0.97) showed no diversity.

f. Reef slope: Table 7 shows various community parameters of 27 families recorded on the reef slope. Acanthuridae, Pomacentridae and Labridae were most conspicious followed by Chaetodontidae, Scaridae and Balistidae to a lessor extent (Fig. 18 B).

Encountered in all samples were individuals belonging to Acanthuridae (1296 nos), Chaetodontidae (597 nos) and Labridae (985 nos) contributing to 20.55, 9.46 and 15.62% respectively. Balistidae was also represented frequently (20 times) with 468 individuals (7.42%).

Commonly occurring families were Mullidae, Pomacentridae, Serranidae, Scaridae, Cirrhitidae, Haemulidae and Zanclidae; their presence ranging from 10 to 19 times. Of these, relatively higher counts were recorded in Pomacentridae with 1119 nos (17.74%) followed by Scaridae with 525 nos (8.32%), Serranidae with 360 nos (5.71%) and Mullidae with 267 nos (4.23%). Other families recorded percentages below 1.55.

Eleven families were intermittent in occurrence with frequencies ranging between 4 and 9. Of these Caesionidae contributed to counts of 159 individuals (2.52%) though it occurred only 5 times. This was followed by Pomacanthidae (74 nos), Tetraodontidae (37 nos), Mugiloididae (35 nos) and Holocentridae (30 nos) contributing to 1.17, 0.59, 0.55 and 0.48%. Other families recorded counts between 4 and 18. Families that appeared rarely (2 to 3 times) were Apogonidae, Diodontidae, Malcanthidae and Nemipteridae with proportions ranging between 0.03 and 1.20%. A single specimen of Lobotidae was observed only once.

Tables 2 to 7. Frequency of occurrence (FO), total abundance (TA), percentage abundance (%) and diversity index (H') for each fish family recorded on the five sub-habitats - live coral, massive coral, rubble, sand and seagrass beds and the reef slope. (January 1991 to June 1992).

Table 2

LIVE CORAL

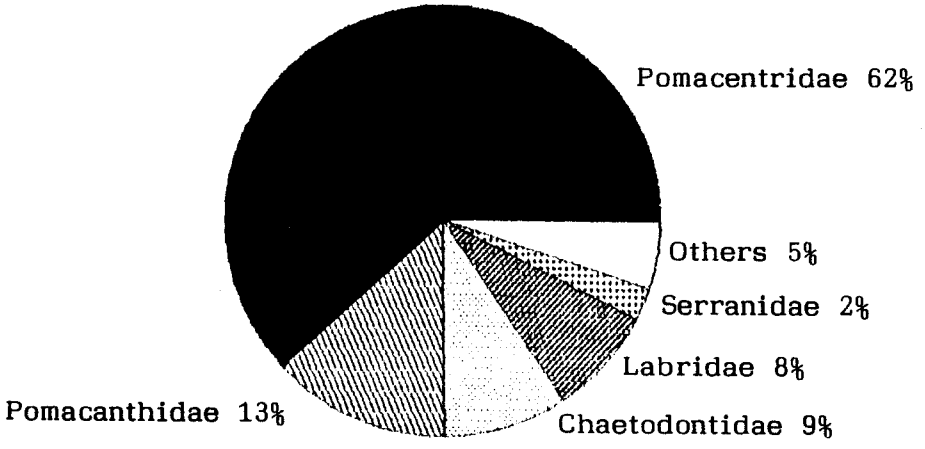
FAMILY		FO	TA	%	H'
1.	Pomacentridae	27	1643	62.10	4.58
2.	Chaetodontidae	36	245	9.27	4.71
3.	Pomacanthidae	25	348	13.16	4.55
4.	Labridae	24	213	8.06	4.33
5.	Serranidae	17	63	2.38	3.61
6.	Balistidae	15	40	1.51	3.30
7.	Scorpaenidae	14	34	1.29	3.48
8.	Cirrhitidae	7	21	0.79	2.68
9.	Muraenidae	6	8	0.30	2.43
10.	Tetraodontidae	5	23	0.87	1.19
11.	Ostraciidae	4	4	0.15	1.50
12.	Acanthuridae	1	1	0.04	0.00
13.	Fistulariidae	1	1	0.04	0.00
14.	Grammistidae	1	1	0.04	0.00

Table 3

MASSIVE CORAL

	FAMILY	FO	TA	%	H'
1.	Labridae	27	906	25.44	4.58
2.	Chaetodontidae	26	275	7.72	4.48
3.	Acanthuridae	25	371	10.42	4.13
4.	Balistidae	19	70	1.97	3.92
5.	Mullidae	19	222	6.22	4.02
6.	Pomacentridae	19	315	8.85	4.07
7.	Serranidae	16	88	2.47	3.68
8.	Scaridae	15	881	24.74	3.42
9.	Haemulidae	9	15	0.42	3.06
10.	Scorpaenidae	8	9	0.25	2.78
11.	Holocentridae	7	25	0.70	2.55
12.	Tetraodontidae	7	28	0.79	2.64
13.	Zanclidae	7	29	0.81	2.59
14.	Cirrhitidae	5	7	0.20	2.63
15.	Mugiloididae	5	17	0.48	2.16
16.	Apogonidae	3	53	1.49	1.39
17.	Grammistidae	3	3	0.08	1.59
18.	Ostraciidae	3	3	0.08	1.59
19.	Caesionidae	2	200	5.62	1.00
20.	Monocanthidae	2	2	0.06	1.00
21.	Muraenidae	2	3	0.08	0.92
22.	Platacidae	2	6	0.17	0.92
23.	Diodontidae	1	1	0.03	0.00
24.	Fistulariidae	1	12	0.34	0.00
25.	Malacanthidae	1	2	0.06	0.00
26.	Pomacanthidae	1	18	0.51	0.00

A. LIVE CORAL



B. MASSIVE CORAL

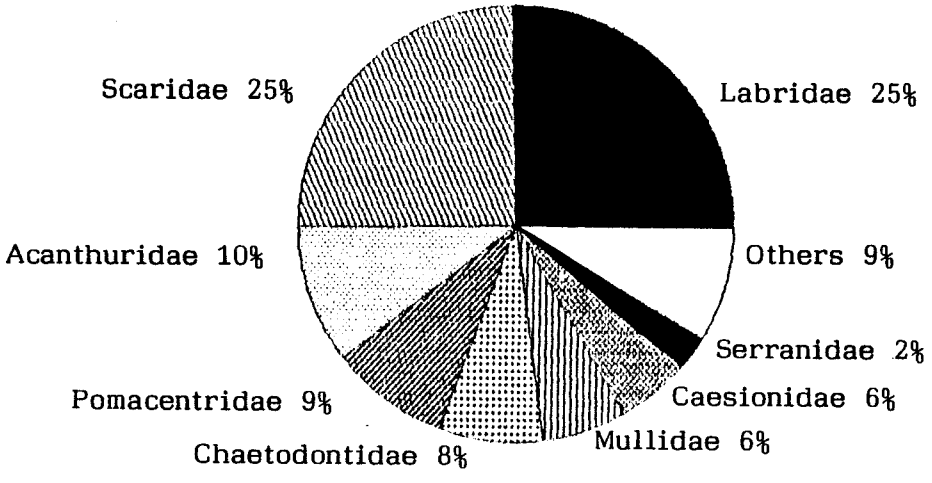


Figure 16 (A & B) : Percentage composition of dominant fish families on live coral and massive coral.

Table 4

RUBBLE

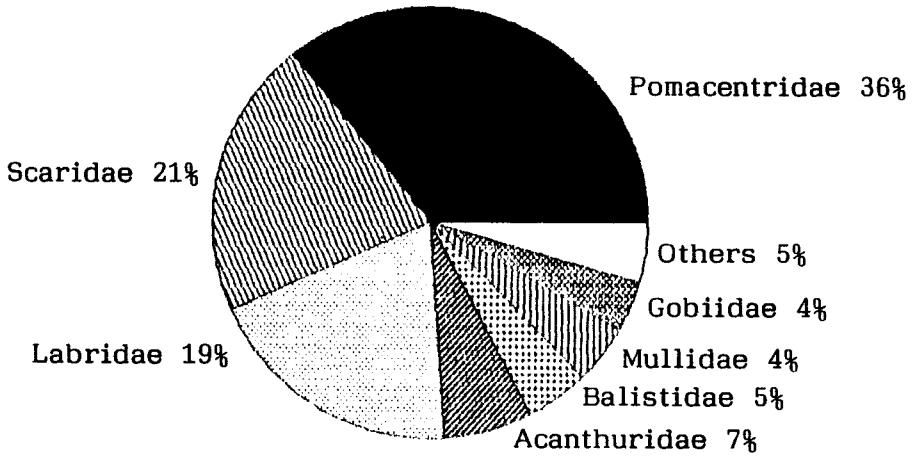
FAMILY		FO	TA	%	H'
1.	Labridae	27	576	19.34	4.80
2.	Pomacentridae	26	1069	35.90	4.47
3.	Balistidae	23	141	4.73	4.22
4.	Acanthuridae	17	195	6.55	3.87
5.	Mullidae	16	132	4.43	3.72
6.	Chaetodontidae	9	32	1.07	2.73
7.	Gobiidae	9	111	3.73	3.11
8.	Muraenidae	8	11	0.37	2.82
9.	Scaridae	8	620	20.82	2.72
10.	Nemipteridae	7	26	0.88	2.40
11.	Plesiopidae	4	31	1.04	1.84
12.	Fistulariidae	3	6	0.20	1.46
13.	Haemulidae	3	3	0.10	0.92
14.	Serranidae	3	19	0.64	1.40
15.	Apogonidae	1	6	0.20	0.00

Table 5

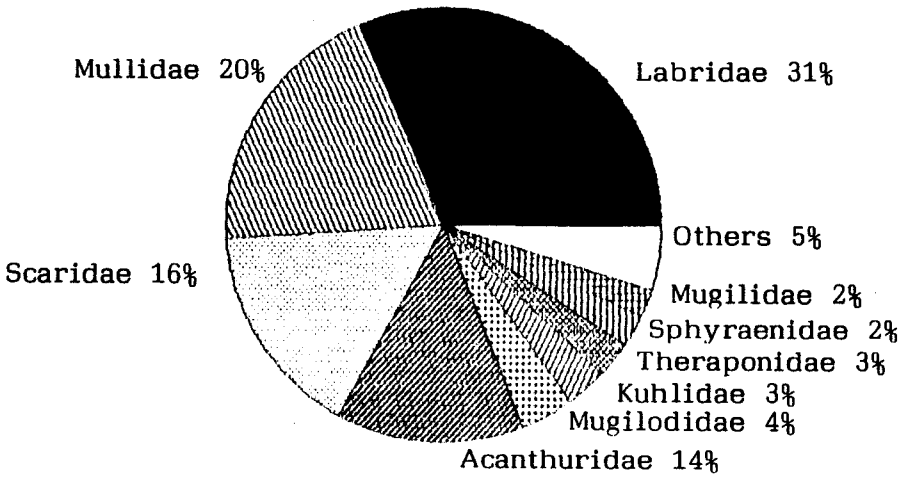
SAND FLATS

FAMILY		FO	TA	%	H'
1.	Labridae	25	402	31.36	4.45
2.	Acanthuridae	22	178	13.88	4.14
3.	Mullidae	22	252	19.66	3.73
4.	Mugiloididae	14	51	3.98	2.86
5.	Polynemidae	9	25	1.95	2.01
6.	Scorpaenidae	9	16	1.25	2.80
7.	Theraponidae	8	36	2.81	2.38
8.	Sphyraenidae	7	31	2.04	2.30
9.	Diodontidae	5	5	0.39	1.76
10.	Mugilidae	5	26	2.03	1.20
11.	Scaridae	5	206	16.07	1.52
12.	Fistulariidae	3	5	0.39	1.58
13.	Kuhlidae	3	39	3.04	0.00
14.	Balistidae	1	2	0.16	0.00
15.	Bothidae	1	1	0.08	0.00
16.	Gobiidae	1	6	0.47	0.00
17.	Ostraciidae	1	1	0.08	0.00

A. RUBBLE



B. SAND FLATS



Fugure 17 (A & B) : Percentage composition of dominant fish families on rubble and sand.

Table 6

SEA GRASS BEDS

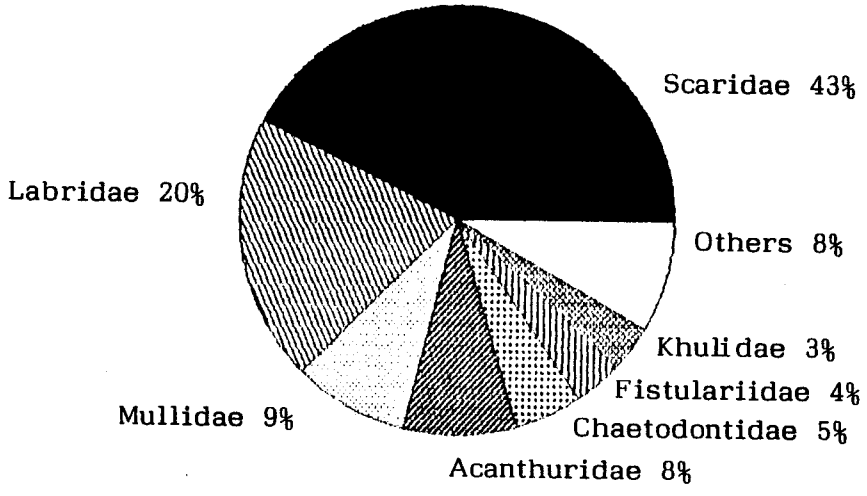
FAMILY	FO	TA	%	H'
1. Labridae	27	824	20.01	4.44
2. Acanthuridae	26	346	8.40	4.28
3. Mullidae	22	355	8.62	4.21
4. Chaetodontidae	21	207	5.03	4.11
5. Scaridae	18	1752	42.55	4.21
6. Monocanthidae	13	33	0.80	3.42
7. Fistulariidae	11	149	3.62	3.06
8. Diodontidae	9	17	0.41	2.90
9. Scorpaenidae	9	18	0.44	2.52
10. Balistidae	8	21	0.51	2.60
11. Pomacentridae	8	40	0.97	2.79
12. Bothidae	6	11	0.27	2.56
13. Zanclidae	6	19	0.46	2.33
14. Tetraodontidae	6	8	0.19	2.52
15. Belonidae	4	38	0.92	1.62
16. Blenniidae	4	42	1.02	1.05
17. Kuhlidae	3	143	3.47	1.18
18. Ostraciidae	3	4	0.10	1.50
19. Polynemidae	3	19	0.46	1.08
20. Sphyraenidae	3	38	0.92	1.15
21. Apogonidae	2	14	0.34	0.00
22. Mugilidae	2	6	0.15	0.92
23. Mugiloididae	2	5	0.12	0.97
24. Malacanthidae	1	1	0.02	0.00
25. Nemipteridae	1	2	0.05	0.00
26. Siganidae	1	2	0.05	0.00
27. Theraponidae	1	4	0.10	0.00

Table 7

REEF SLOPE

FAMILY	FO	TA	%	H'
1. Acanthuridae	22	1296	20.55	4.26
2. Chaetodontidae	22	597	9.46	4.19
3. Labridae	22	985	15.62	4.31
4. Balistidae	20	468	7.42	3.93
5. Mullidae	19	267	4.23	4.13
6. Pomacentridae	19	1119	17.74	3.98
7. Serranidae	16	360	5.71	2.75
8. Scaridae	15	525	8.32	3.10
9. Cirrhitidae	12	57	0.90	3.12
10. Haemulidae	11	97	1.54	2.74
11. Zanclidae	10	50	0.79	2.90
12. Tetraodontidae	9	37	0.59	2.98
13. Holocentridae	8	30	0.48	2.81
14. Pomacanthidae	8	74	1.17	1.63
15. Ostraciidae	7	14	0.22	2.61
16. Grammistidae	6	9	0.14	2.27
17. Mugiloididae	6	35	0.55	2.38
18. Scorpaenidae	6	18	0.29	2.32
19. Caesionidae	5	159	2.52	2.10
20. Monocanthidae	4	5	0.08	1.91
21. Muraenidae	4	4	0.06	2.00
22. Platacidae	4	12	0.19	1.92
23. Apogonidae	3	76	1.20	1.26
24. Diodontidae	2	3	0.05	0.92
25. Malacanthidae	2	2	0.03	1.00
26. Nemipteridae	2	8	0.13	1.00
27. Lobotidae	1	1	0.02	0.00

A. SEA GRASS



B. REEF SLOPE

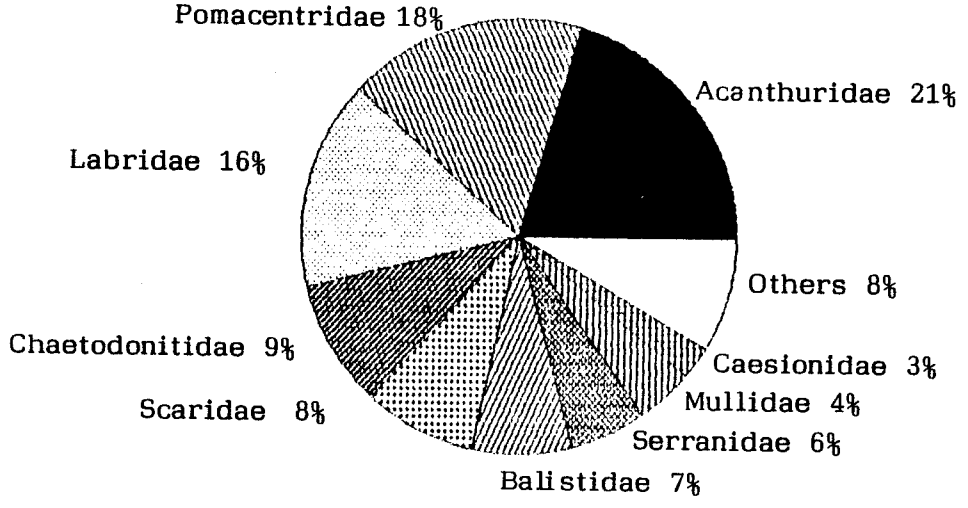


Figure 18 (A & B) : Percentage composition of dominant fish families on seagrass and reef-slope.

Diversities greater than 4 were recorded by four families, namely, Acanthuridae (4.26), Chaetodontidae (4.19), Labridae (4.31), and Mullidae (4.13). This was followed by Pomacentridae (3.98), Balistidae (3.93), Scaridae (3.10) and Cirrhitidae (3.12). Diversities for Serranidae, Haemulidae, Zanclidae, Tetraodontidae, Holocentridae, Ostraciidae, Grammistidae, Mugiloididae, Scorpaenidae, Caesionidae and Muraenidae ranged between 2.00 and 2.98, while values for Pomacanthidae, Monacanthidae, Platacidae, Apogonidae, Malacanthidae, and Nemipteridae ranged between 1.00 and 1.91. Diodontidae recorded low diversity (0.92) while Lobotidae showed no diversity.

2. Seasonal variation in community parameters.

a. Live coral: In pre-monsoon ('91) the total number of individuals recorded in all samples ranged between 61 and 150. In general, February, March and April registered least fish counts ranging between 61 and 99 individuals. The highest number (150) was recorded in January 1 (Table 8 A) followed by 115 counts in March 4 and 108 in February 2. During pre-monsoon of '92 (Table 8 D) total counts appeared stable in a majority of samples (82 to 86 nos) except in February 2 (57 nos) and April 6 (61 nos). A greater variation in total counts was evident during monsoon. 240 individuals were recorded in May 1 ('92) while the minimum was 63 in June 3, '91 (Table 8 E & B). Four

samples two in May 1, 2 '91 and one each in May 1 and June 2, '92 recorded more fishes (109, 106, 126 and 240 respectively), when compared to other monsoon months (Table 8 B & E). In post-monsoon (Table 8 C) higher counts were recorded in October 3 (141 nos) and November 6 (129 nos) followed by 123 individuals in September 2. Rest of the samples did not show significant variation (72 to 92 nos).

Total number of families in the sub-habitat remained relatively constant, varying between 5 and 8 families, except in May 2, '91 (Table 8 B) which recorded 9 families.

Family diversity during pre-monsoon indicated a maximum of 2.34 in March 5, '91 and a minimum of 1.53 in April '92. Comparitively high diversities (2.11 and 1.99) were observed in February 2 and March 4 '92 (Table 8 D). Variation in diversity during monsoon was high (0.81 in May 1, '92 to 3.69 in May 2, '91). High diversities were also recorded during June 3, (2.28) and July 4, (2.10). Post-monsoon registered relatively less variation(1.55 and 1.71) except in November 6 (2.25).

Evenness in distribution during pre-monsoon was not stable (0.55 to 0.83). March 5, '91 and February 2, '92 registered an even distribution of 0.83 and 0.91 respectively (Table 8 A & D). In monsoon a relatively even distribution (0.88) was seen in June 3, '91 while it was most uneven (0.31) in May 1, '92. During

post-monsoon, November 6, (0.80) and December 7 (0.72) recorded even distribution while in others it varied between 0.53 to 0.66 (Table 8 C).

b. Massive coral: Total number of individuals during the pre-monsoon of both years showed high variation (Table 9 A & D). In 1991 counts varied between 87 (March 5) and 155 individuals (February 2) while in the subsequent year the magnitude of variation was greater with 57 (February 2) to 347 individuals (April 6). Monsoon indicated a similar trend with 54 nos (August 5, '91) and 152 nos (May 1, '92). Highest counts (212 and 296) among the seasons were obtained in October 4 and November 5 (post-monsoon). Total counts fluctuated between 41 and 296 in the same season (Table 9 C).

Family composition during all seasons varied between a minimum of 6 and a maximum of 12 families. In general 8 to 10 families were frequently found during the pre-monsoon ('91 & '92). Variation of family composition (7 to 12) was high during monsoon, while in the post-monsoon it was generally between 8 and 10 families.

Family diversity in pre-monsoon of both years was above 2.00 (Table 9 A & D). The maximum was 2.75 followed by 2.06 in March 3 and February 2 respectively in '92 (Table 9 D).

Monsoon accounted for a variation between 1.66 and 2.88 (Table 9 E & B). Diversity during post-monsoon was generally above 2.00 except in September 1 when it was 1.94 (Table 9 C).

Distribution was most even in April 6, '91 (0.85) and March 3, '92 (0.87), while rest of the samples did not vary much (0.73 to 0.80) during pre-monsoon except in April 5, 6 '92 (0.69 and 0.63). An even distribution was observed in June 2, '92 (0.89) with a minimum (0.59) also observed in May 1 during the same year (Table 9 E). Other samples showed evenness between 0.64 to 0.83. The most even distribution among all seasons in the sub-habitat was in October 3 (0.90) during post-monsoon. Other samples indicated a relatively low but stable distribution ranging between 0.70 to 0.76 (Table 9 C).

c. Rubble: Total fish counts recorded during pre-monsoon was high in the two years. The minimum and maximum numbers recorded in '91 was 79 and 157, while in '92 it was 39 and 167 (Table 10 A & D). A similar trend was observed during monsoon of '92 (87 to 177 nos) and the post-monsoon '91 (53 to 161 nos). Except for counts in May 2, '91 (93 nos) and June 2, '92 (87 nos), monsoon counts remained steady above 100 (Table 10 B & E).

Family composition on the sub-habitat varied greatly (4 to 9), while 5 to 7 families frequently occurred. 9 families (maximum) were observed in January 1, '91 (Table 10 A) and a minimum of 4 families were found in July 4, '91 (Table 10 B).

Family diversity was also inconsistent in the three seasons. During pre-monsoon (Table 10 A) it varied between 1.11 and 2.54, both recorded in February 2, 1 in '91, while in '92 samples indicated relatively stable diversities, between 1.72 and 2.24, (Table 10 D). Trends in monsoon (1.61 to 2.62) and post-monsoon (1.33 to 2.16) also varied greatly (Table 10 B, E & C).

During pre-monsoon a relatively even distribution (0.80 each) in January 1 and March 5, '91 and February 2, '91 was observed. Except for an uneven distribution (0.43) in February 2, '91 other samples remained relatively stable (0.62 to 0.77). Of all the samples, the most even distribution (0.93) of families was recorded in May 1, '91 (monsoon). Other monsoon samples varied between 67 to 0.84 (Table 10 E & B). October 4 and November 6 had relatively even distribution (0.83 and 0.84) in post-monsoon while other samples registered moderate evenness.

d. Sand flats: Total number of fishes recorded in the pre-monsoon (1991) varied between 28 and 84 individuals in March 4 and February 2 respectively. 67 individuals were recorded in January 1. Magnitude of variation was greater in pre-monsoon ('92) with 27 individuals in March 3 and 129 in April 6 (Table 11 D). Monsoon recorded 21 to 135 individuals in May 1, '91 and June 2, '92 respectively (Table 11 B & E). Except for a minimum of 14 and 24 individuals recorded in December 7 and October 4 respectively, total counts were relatively stable between 33 and 43 during post-monsoon (Table 11 C).

Highest family representation (8) was found in pre-monsoon ('91) and a minimum of 4 families generally occurred in all seasons. Generally, the family composition varied between 5 and 7 except in post-monsoon, when a majority of samples accounted for the presence of 4 families (Table 11 C). 3 families in post-monsoon was the least recorded in October 4 (Table 11 C).

Family diversity during pre-monsoon ranged from 0.86 (minimum) in April 6, '91 to 2.32 (maximum) in March 5, '91 while in the same season during '92, diversity values ranged between 1.70 in February 2 and 2.30 in January 1 (Table 11 A & D). Diversity variation was similar in monsoon (1.42 to 2.38) and post-monsoon (1.42 to 2.42). Relatively higher diversities (2.18 and 2.38) were observed in May 1 and July 4 (monsoon) and in November 5, 6 (2.06 and 2.42) in post-monsoon (Table 11 C).

During pre-monsoon the distribution of individuals in the families showed highest evenness (0.96 and 0.92) in March 4 and April 5, '92, while it was uneven in April 6 '91 and April 6 '92 with values of 0.37 and 0.49 respectively (Table 11 A & D). Evenness in other samples during pre-monsoon seasons varied between 0.63 to 0.89. Evenness of distribution varied significantly (0.51 to 0.94) during monsoon, while a relatively stable distribution (0.71 to 0.81) was noted in post-monsoon, except during November 6, when it was 0.94.

e. Seagrass beds: Total fish counts in the sub-habitat varied greatly. In pre-monsoon of '91, 60 and 310 individuals were recorded in April 7 and March 4 respectively. Other samples accounted for counts between 185 and 213 individuals (Table 12 A). In comparison, the pre-monsoon of '92 showed less variation (139 to 204) on total fish counts (Table 12 D). Magnitude of variation was high in monsoon (56 to 203 nos) and post-monsoon (52 to 50 nos). Highest counts (350) were recorded in September 2 (post-monsoon) followed by 310 individuals in March 4, '91 (pre-monsoon).

Number of families in most samples ranged between 7 and 10. A maximum of 12 families and a minimum of 6 families were observed in May 1, 2, '91 (Table 12 B), while in post-monsoon, October 3, accounted for 5 families (Table 12 C).

Family diversity was high in five samples taken in February 2, 3, March 4, 5 and April 7 (2.08, 2.13, 2.61, 2.32 and 2.16 respectively) during pre-monsoon of '91 (Table 12 A). Samples in the same season in '92 indicated diversities below 2.00 (1.64 to 1.94). Monsoon accounted for high diversities (above 2.00) with a maximum of 2.71 in July 4, (Table 12 B & E) except in a single sample (1.84) taken in May 1, '92. Diversity in post-monsoon was relatively low (Table 12 C) with values below 2.00 except in September 2 (2.27) and October 4 (2.52).

Fish distribution, though relatively uneven, was generally, stable in pre-monsoon of '91 (0.61 to 0.79) and '92 (0.52 to 0.65), while the most even distribution (0.90) was encountered in July 4 (Table 12 B). This was followed by a relatively even distribution in May 2 and June 3 of '91 (0.82 each) and 0.89 in June 2, '92 (Table 12 B & E). Evenness varied between 0.55 in September 1 and 0.81 in October 3, during post-monsoon (Table 12 D).

f. Reef slope: Fish counts were generally of a higher magnitude on the reef slope region. A maximum of 414 individuals in April 7, '91 and a minimum of 169 individuals in March 3, '92 were recorded in the pre-monsoon (Table 13 A & D). Fish counts in other samples during pre-monsoon ranged between 228 and 388. Counts in monsoon varied between 141 (May 1, '92) and 340 (May 1, '91). Highest number of fishes (387) were recorded in September 1 while the least was 199 individuals in October 3 during post-monsoon (Table 13 C).

Family composition varied greatly between 9 and 19 families. In pre-monsoon, a maximum of 16 families were recorded in February 3, March 5 and April 6 ('91), while the minimum (9) was recorded in February 2, '91 and March 3, '92 (Table 13 A & D). 10 to 14 families occurred during monsoon while in the post-monsoon, the highest number of families (19) occurred in October 4 and a minimum of 9 in November 5 (Table 13 B, E & C).

Tables 8 to 13. Total number of individuals (I), number of families (F), diversity index (H') and evenness inded (J') for each of the census conducted during pre-monsoon, monsoon and post-monsoon seasons on the five sub-habitats and reef slope (1991 to 1992).

Table 8

LIVE CORAL

A PRE-MONSOON 1991

Sample No.	1	2	3	4	5	6	7
	J	F	F	M	M	A	A
I	150	108	81	115	61	99	86
F	6	7	5	8	7	7	6
M'	1.67	1.55	1.55	1.85	2.34	1.73	1.58
J'	0.65	0.55	0.67	0.62	0.83	0.62	0.61

B MONSOON

	MY	MY	J	JY	A
I	109	106	63	65	85
F	5	9	6	7	7
H'	1.62	3.69	2.28	2.10	1.56
J'	0.70	0.66	0.88	0.75	0.56

C POST-MONSOON

	S	S	O	O	N	N	D
I	72	123	141	78	85	129	91
F	8	6	6	6	6	7	5
H'	1.65	1.55	1.68	1.38	1.71	2.25	1.67
J'	0.55	0.60	0.65	0.53	0.66	0.80	0.72

D PRE-MONSOON 1992

	J	F	M	M	A	A
I	84	57	82	86	83	61
F	7	5	7	8	5	5
H'	1.76	2.11	1.71	1.99	1.86	1.53
J'	0.63	0.91	0.61	0.66	0.80	0.66

E MONSOON (2 samples) May, June | I = 126, 240; H' = 1.80, 0.81; J' = 0.64, 0.31
F = 7, 6.

Table 9

MASSIVE CORAL

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	118	155	130	126	87	106	88
	F	9	9	11	10	8	6	9
	H'	2.31	2.55	2.65	2.49	2.24	2.21	2.35
	J'	0.73	0.80	0.77	0.75	0.75	0.85	0.74
B	MONSOON							
		MY	MY	J	JY	AG		
	I	81	57	118	89	54		
	F	12	7	11	8	7		
	H'	2.53	1.79	2.88	2.30	1.96		
	J'	0.71	0.64	0.83	0.77	0.70		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	82	116	41	212	296	198	72
	F	6	8	8	9	10	11	72
	H'	1.94	2.27	2.71	2.30	2.36	2.43	2.26
	J'	0.75	0.76	0.90	0.73	0.71	0.70	0.75
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	188	57	117	197	206	347	
	F	10	6	9	8	10	10	
	H'	2.37	2.06	2.75	2.20	2.30	2.08	
	J'	0.71	0.80	0.87	0.73	0.69	0.63	

E MONSOON (2 samples) May, June | I = 152, 66; H' = 1.66, 2.66; J' = 0.59, 0.89; F = 7, 8.

Table 10

RUBBLE

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	157	89	99	145	79	103	97
	F	9	6	5	7	6	4	6
	H'	2.54	1.11	1.79	2.08	2.08	1.33	1.74
	J'	0.80	0.43	0.77	0.74	0.80	0.67	0.67
B	MONSOON							
		MY	MY	J	JY	AG		
	I	132	93	122	100	132		
	F	7	7	5	4	6		
	H'	2.62	2.14	1.64	1.61	2.16		
	J'	0.93	0.76	0.71	0.81	0.84		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	121	80	141	53	57	78	161
	F	7	6	5	5	6	6	6
	H'	2.07	1.91	1.33	1.93	2.04	2.16	1.73
	J'	0.74	0.74	0.57	0.83	0.79	0.84	0.67
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	160	78	167	39	166	66	
	F	7	7	7	5	8	5	
	H'	1.73	2.24	1.83	1.72	1.93	1.69	
	J'	0.62	0.80	0.65	0.74	0.64	0.73	
E	MONSOON (2 samples) May, June	I = 177, 87; H' = 1.95, 1.91; J' = 0.69, 0.82; F = 7, 5.						

Table 11

SAND FLATS

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	67	84	35	28	33	32	47
	F	5	8	5	5	7	5	6
	H'	1.61	2.29	1.79	1.97	2.32	0.86	1.63
	J'	0.69	0.76	0.77	0.85	0.83	0.37	0.63
B	MONSOON							
		MY	MY	J	JY	A		
	I	21	45	45	73	29		
	F	5	4	6	6	6		
	H'	2.18	1.57	1.74	2.38	2.14		
	J'	0.94	0.79	0.67	0.92	0.83		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	43	36	33	24	36	40	14
	F	4	4	4	3	6	6	4
	H'	1.57	1.50	1.61	1.23	2.06	2.42	1.42
	J'	0.79	0.75	0.81	0.78	0.80	0.94	0.71
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	50	43	27	38	44	129	
	F	6	5	6	4	5	5	
	H'	2.30	1.70	2.11	1.91	2.14	1.14	
	J'	0.89	0.73	0.82	0.96	0.92	0.49	
E	MONSOON (2 samples) May, June	I = 51, 135; H' = 1.78, 1.42; J' = 0.77, 0.51; F = 5, 7.						

Table 12

SEA GRASS BEDS

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	201	185	190	310	213	205	60
	F	8	8	9	10	10	8	7
	H'	1.84	2.08	2.13	2.61	2.32	1.97	2.16
	J'	0.61	0.69	0.67	0.79	0.70	0.66	0.77
B	MONSOON							
		MY	MY	J	JY	AG		
	I	203	114	90	102	129		
	F	12	6	8	8	9		
	H'	2.42	2.13	2.46	2.71	2.27		
	J'	0.68	0.82	0.82	0.90	0.72		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	148	350	52	64	146	173	63
	F	7	10	5	9	6	9	6
	H'	1.55	2.27	1.87	2.52	1.50	1.96	1.71
	J'	0.55	0.68	0.81	0.79	0.58	0.62	0.66
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	204	154	163	139	171	151	
	F	9	7	7	9	9	7	
	H'	1.92	1.64	1.83	1.64	1.94	1.67	
	J'	0.61	0.58	0.65	0.52	0.61	0.59	
E	MONSOON (2 samples) May, June	I = 56, 58; H' = 1.84, 2.49; J' = 0.66, 0.89; F = 7, 7.						

Table 13

REEF SLOPE

Sample No.		1	2	3	4	5	6	7
A PRE-MONSOON 1991								
		J	F	F	M	M	A	A
	I	388	371	341	228	237	253	414
	F	14	9	16	8	16	16	13
	H'	2.65	2.77	3.28	2.56	3.05	3.29	2.68
	J'	0.70	0.87	0.82	0.85	0.76	0.82	0.72
B MONSOON								
		MY	MY	AG				
	I	340	304	251				
	F	11	14	11				
	H'	2.30	2.47	2.75				
	J'	0.66	0.65	0.79				
C POST-MONSOON								
		S	S	O	O	N	D	
	I	387	270	199	260	307	218	
	F	12	11	10	19	9	10	
	H'	2.85	2.34	2.56	3.75	2.48	2.47	
	J'	0.79	0.68	0.77	0.88	0.78	0.74	
D PRE-MONSOON 1992								
		J	F	M	A	A		
	I	256	386	169	288	300		
	F	8	14	9	15	10		
	H'	2.20	2.98	2.78	2.96	2.56		
	J'	0.73	0.78	0.88	0.76	0.77		
E MONSOON (1 sample) May		I = 141; H' = 2.76; J' = 0.83; F = 10.						

Family diversity values were generally above 2.20. On three occassions (February 3, March 5 and April 6) high diversities of 3.28, 3.05 and 3.29 were observed in the pre-monsoon of '91 while a maximum of 2.98 in February 2 was recorded in the same season in '92 (Table 13 A & D). In monsoon the values varied between 2.30 to 2.76. Highest diversity (3.75) was recorded in October 4 during post-monsoon with the rest ranging between 2.34 and 2.85 (Table 13 C).

Distribution of individuals in pre-monsoon was relatively low in January 1, (0.70) and April 7 (0.72) in '91 and January 1 (0.73) of '92. Other samples registered values between 0.76 and 0.88 (Table 13 A & D). Compared to pre-monsoon, the monsoon and post-monsoon seasons showed relatively low evenness between 0.66 to 0.83 and 0.68 to 0.79 respectively (Table 13 B, E & C) except for an evenness of 0.88 in October 4 during post-monsoon. In general, fish were more evenly distributed in pre-monsoon season.

3. Distribution of Families

Table 14 shows the distribuion of all families on various sub-habitats, habitat diversity and evenness. A total of 38 families were recorded from all sub-habitats during the period under investigation. Labridae occurred most frequently (130 times) on all five sub-habitats summing upto 2921 individuals. Representatives of the family showed greatest abundance (31.02%) on the massive coral zone followed

by seagrass beds (28.21%), rubble (19.72%) and sand flats (13.76%) (Fig. 19 D). Few individuals (7.29%) were observed on live coral zones. Labridae accounted for relatively even distribution (0.82) with a high habitat diversity of 1.91.

Of 135 samplings in total, Acanthuridae occurred 91 times recording 1091 individuals from all sub-habitats. Except for a single appearance on live coral, the family represented other habitats with frequencies between 17 and 26 times. Excluding the live coral zone, individuals contributed to relatively high proportions (34.01%) on the massive coral zone followed by seagrass beds (31.71%), rubble (17.87%) and sand flats with 16.32% (Fig. 19 A). With a habitat diversity of 1.88, individuals of Acanthuridae were evenly distributed (0.81) on the sub-habitats.

Pomacentridae and Chaetodontidae occurred 80 and 82 times respectively, on four sub-habitats. Pomacentridae showed higher abundance (3067 nos) compared to Chaetodontidae (759 nos). 36.23% of chaetodontids were found on massive coral followed by 32.28% on live coral (Fig. 19 C). Seagrass beds recorded 27.27% of chaetodontids while it was least (4.22%) on rubble (Fig. 19 C). More than 50% of the pomacentrids were observed on live coral followed by 34.86% on rubble (Fig. 19 G). The occurrence of Pomacentridae on massive coral and seagrass beds was least (less than 12%). Habitat diversity and evenness in this group was low (1.34 and 0.67) compared to that in Chaetodontidae (1.72 and 0.86).

Mullidae occurred 79 times, recording 961 individuals. Its presence was greatest (36.94%) on seagrass beds followed by sand (26.22%) and massive coral with 23.10% (Fig. 19 E). Mullidae was amongst the most evenly distributed families (0.96) recording a high diversity of 1.92.

Balistidae accounted for 274 individuals occurring 66 times. Greatest representation was encountered on rubble (51.46%) followed by massive coral (25.55%) and live coral with 14.50% (Fig. 19 B). While 8 occurrences were recorded on seagrass, sand flats recorded a single occurrence (7.66 and 0.73% respectively). With a moderate evenness of 0.77, a relatively high diversity (1.78) was recorded.

Scaridae was the most abundant group with 3459 individuals though it occurred only 46 times. Almost 50% of individuals recorded were found on seagrass beds followed by massive coral (25.47%) and rubble (17.92%).

A total of 77 individuals belonging to Scorpaenidae, occurred 40 times. It appeared 14 times on live coral contributing to 44.16%. Their abundance was comparable on seagrass (23.38%) and sand flats (20.78%). Only 11.68% of individuals were recorded from massive corals. Distribution on the sub-habitats was moderately even (0.88) with a relatively high diversity of 1.76.

Serranidae appeared 36 times with 170 individuals mostly recorded on live and massive coral zones with proportions of 37.06% and 51.76%. Only 11.18% were found to inhabit rubble zones. With an evenness value of 0.86, Serranidae had a relatively low habitat diversity (1.37).

Though Pomacanthidae was encountered only 26 times it accounted to a total abundance of 366 individuals, mainly recorded on live coral zones (95.08%). (Fig. 19 F). Diversity and evenness were however low (0.68 and 0.43 respectively).

Of the 73 individuals recorded by Mugiloididae, most of them (69.86%) dominated sand flats followed by the massive coral (23.29%). Habitat diversity and evenness was ´0.95 and 0.60 respectively .

With a total of 59 individuals, Tetraodontidae appeared mainly on massive corals (47.46%) followed by live coral zones (38.98%), however a few (13.56%) were also found on seagrass beds. With a diversity of 1.18, individuals were relatively even (0.74) in distribution.

50% of the individuals belonging to Muraenidae were found on rubble zones followed by live coral zones (36.36%) with a habitat diversity of 1.40 and a fairly even distribution (0.88).

Individuals of Diodontidae and Monacanthidae occurred 9 and 13 times on seagrass beds accounting for 73.91% and 94.29% of individuals respectively. 21.74% of diodontids were also recorded on sand flats. Of the two, Monacanthidae accounted for low diversity (0.32) and evenness, while in Diodontidae it was 0.97 and 0.61 respectively.

Members of Cirrhitidae dominated on live coral (75.00%) followed by massive coral (25%), the habitat diversity and evenness being 0.93. Haemulidae was predominant on massive coral zones (83.33%) and occasionally on rubble (16.67%) with habitat diversity and evenness of 0.74.

A total of 44 individuals of Polynemidae were more or less evenly distributed (0.99) on sand flats (56.82%) and seagrass beds (43.18%) with a low habitat diversity of 0.99. Members of Ostraciidae were also fairly even in distribution (0.93) with a relatively high habitat diversity of 1.85. Sub-habitats of live coral and seagrass beds were equally represented (33.33% each) followed by 25% of individuals on massive coral.

With a total count of 117 individuals Gobiidae was dominant on rubble (94.87%) with a habitat diversity of 1.10 and evenness of 0.69. The most even distribution (1.00) was recorded by Sphyraenidae with 44.93% on sand flats and 55.07% seagrass. Habitat diversity was 1.00.

Theraponidae and Bothidae registered low evenness and habitat diversity with the former dominating on sand flats (90.00%) and the latter on seagrass bed (91.67%). Holocentrids were mainly found on massive coral. Mugilidae registered a total count of 32 nos of which most occurred on sand flats (81.25%) followed by seagrass beds (18.75%) with a diversity of 0.74.

Table 14. Habitat preference as indicated by frequency of occurrence and percentage abundance on the five sub-habitats - live coral (L), massive coral (M), rubble (R), sand (S) and seagrass beds (SG); pooled frequency of occurrence and abundance, habitat diversity (H') and evenness (J') indices of fish families encountered during censuses.

	FAMILY	FO	TA	FREQUENCY OF OCCURRENCE					PERCENTAGE ABUNDANCE					H'	J'
				L	M	R	S	SG	L	M	R	S	SG		
1.	Labridae	130	2921	24	27	27	25	27	7.29	31.02	19.72	13.76	28.21	1.91	0.82
2.	Acanthuridae	91	1091	1	25	17	22	26	0.09	34.01	17.87	16.32	31.71	1.88	0.81
3.	Chaetodontidae	82	759	26	26	9	-	21	32.28	36.23	4.22	-	27.27	1.72	0.86
4.	Pomacentridae	80	3067	27	19	26	-	8	53.57	10.27	34.86	-	1.30	1.34	0.67
5.	Mullidae	79	961	-	19	16	22	22	-	23.10	13.74	26.22	36.94	1.92	0.96
6.	Balistidae	66	274	15	19	23	1	8	14.60	25.55	51.46	0.73	7.66	1.78	0.77
7.	Scaridae	46	3459	-	15	8	5	18	-	25.47	17.92	5.96	50.65	1.62	0.70
8.	Scorpaenidae	40	77	14	8	-	9	9	44.16	11.68	-	20.78	23.38	1.76	0.88
9.	Serranidae	36	170	17	16	3	-	-	37.06	51.76	11.18	-	-	1.37	0.86
10.	Pomacanthidae	26	366	25	1	-	-	-	95.08	4.92	-	-	-	0.68	0.43
11.	Mugiloididae	21	73	-	5	-	14	2	-	23.29	-	69.86	6.85	0.95	0.60
12.	Fistularidae	19	173	1	1	3	3	11	0.58	6.94	3.47	2.89	86.12	0.63	0.27
13.	Tetraodontidae	18	59	5	7	-	-	6	38.98	47.46	-	-	13.56	1.18	0.74
14.	Muraenidae	16	22	6	2	8	-	-	36.36	13.64	50.00	-	-	1.40	0.88
15.	Diodontidae	15	23	-	1	-	5	9	-	4.35	-	21.74	73.91	0.97	0.61
16.	Monocanthidae	15	35	-	2	-	-	13	-	5.71	-	-	94.29	0.32	0.32
17.	Zanclidae	13	48	-	7	-	-	6	-	60.42	-	-	39.58	1.31	0.83
18.	Cirrhitidae	12	28	7	5	-	-	-	75.00	25.00	-	-	-	0.93	0.93
19.	Haemulidae	12	18	-	9	3	-	-	-	83.33	16.67	-	-	0.74	0.74
20.	Polynemidae	12	44	-	-	-	9	3	-	-	-	56.82	43.18	0.99	0.99
21.	Ostraciidae	11	12	4	3	-	1	3	33.33	25.00	-	8.34	33.33	1.85	0.93
22.	Gobiidae	10	117	-	-	9	1	-	-	-	94.87	5.13	-	1.10	0.69
23.	Sphyraenidae	10	69	-	-	-	7	3	-	-	-	44.93	55.07	1.00	1.00
24.	Theraponidae	9	40	-	-	-	8	1	-	-	-	90.00	10.00	0.47	0.47
25.	Bothidae	7	12	-	-	-	1	6	-	-	-	8.33	91.67	0.40	0.40
26.	Holocentridae	7	25	-	7	-	-	-	-	100.00	-	-	-	0.00	0.00
27.	Mugilidae	7	32	-	-	-	5	2	-	-	-	81.25	18.75	0.74	0.74
28.	Nemipteridae	8	28		-	7	-	1	-	-	92.86	-	7.14	0.45	0.45
29.	Apogonidae	6	73	-	3	1	-	2	-	72.60	8.22	-	19.18	1.08	0.68
30.	Kuhlidae	6	182	-	-	-	3	3	-	-	-	21.43	78.57	1.00	1.00
31.	Belonidae	4	38	-	-	-	-	4	-	-	-	-	100.00	0.00	0.00
32.	Blenniidae	4	42	-	-	-	-	4	-	-	-	-	100.00	0.00	0.00
33.	Grammistidae	4	4	1	3	-	-	-	25.00	75.00	-	-	-	0.81	0.81
34.	Plesiopidae	4	31	-	-	4	-	-	-	-	100.00	-	-	0.00	0.00
35.	Caesionidae	2	200	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
36.	Malacanthidae	2	3	-	1	-	-	1	-	66.67	-	-	33.33	0.92	0.92
37.	Platacidae	2	6	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
38.	Siganidae	1	2	-	-	-	-	1	-	-	-	-	100.00	0.00	0.00

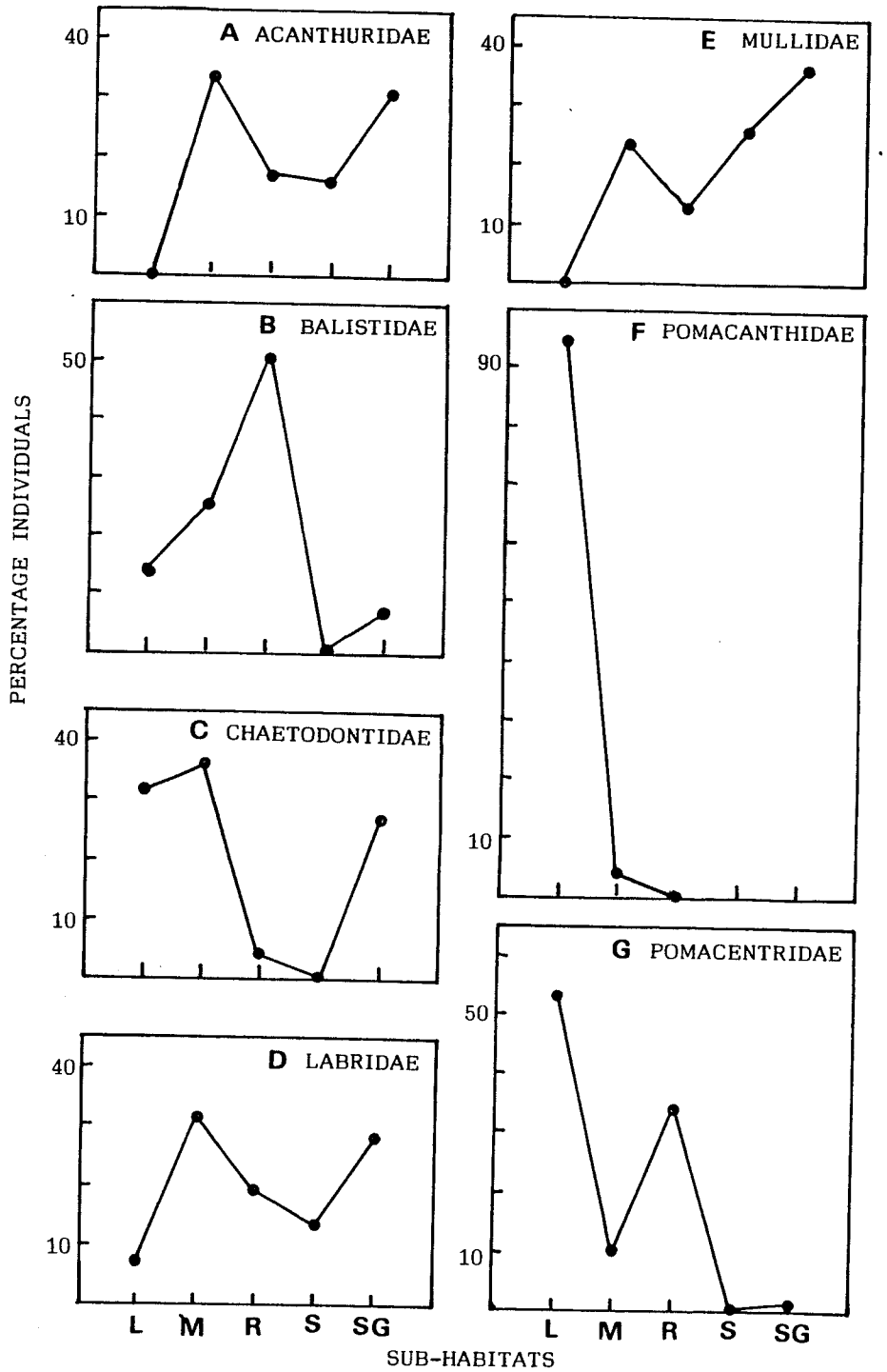


Figure 19 (A to G) Percentage of individuals of seven dominant fish families on live coral (L), massive coral (M), rubble (R), Sand (S) and seagrass beds (SG).

A majority of the 73 apogonids recorded were found on massive coral zones (72.60%) followed by 19.18% on seagrass beds with a relatively high habitat diversity 1.08. 182 kuhlids were distributed on sand flats (21.43%) and seagrass (78.57%) with habitat diversity and evenness of 1.00. Belonidae and Blenniidae accounted for a zero diversity with all specimens (38 and 42 respectively) recorded only from seagrass beds. Individuals belonging to Plesiopidae were found on rubble while those belonging to Caesionidae and Platacidae were found on massive coral zones.

Only 4 individuals of Grammistidae were encountered mainly on massive coral region (75.00%) followed by live coral zones (25.00%) with diversity and evenness of 0.81 each. Similarly, only 3 individuals of Malacanthidae were recorded mainly from massive coral (66.67%) and seagrass (33.33%). Siganids were recorded only from seagrass.

4. Presence or absence of families

Family representation on the five sub-habitats and reef slope is pictorially depicted in Fig. 20.

Of the 38 families only 3 families, namely, Acanthuridae, Balistidae and Labridae were found on all sub-habitats and the reef slope. Individuals of Chaetodontidae and Pomacentridae were not represented on sand flats while Mullidae and Scaridae did not frequent the live coral zone. Members belonging to Ostraciidae were absent on rubble.

Diodontidae and Mugiloididae did not occur on live coral and rubble, while Apogonidae were not present on live coral and sand. Muraenidae and Serranidae were absent on sand and seagrass, while Tetraodontidae was not recorded from rubble and sand.

Members of Cirrhitidae and Grammistidae were recorded from regions of live coral, massive coral and reef slope. Haemulidae was present on massive coral, rubble and reef slope. Malacanthidae and Monocanthidae followed a similar pattern, except that it was absent on rubble, but present on seagrass. Individuals of Pomacanthidae were recorded on live coral, massive coral, and reef slope while Zanclidae showed presence on massive coral, seagrass and reef slope.

Bothidae, Kuhlidae, Mugilidae, Polynemidae, Sphyraenidae and Theraponidae were present only on two sub-habitats, namely sand and seagrass, while Caesionidae, Holocentridae and Platacidae were present on massive coral and reef slope. Gobiidae was recorded only from rubble and sand, while Nemipteridae was found on rubble, seagrass and reef slope.

Belonidae, Blenniidae and Siganidae were present only on seagrass while Platacidae and Plesiopidae were recorded from massive coral and rubble respectively.

5. Community diversity

Diversity values obtained for each sub-habitat and the reef slope are given in Table 15. With regard to families, highest diversity was

Figure 20 Presence or absence of fish families on the five sub-habitats - live coral (L), massive coral (M), rubble (R), sand (S), seagrass beds (SG); and the reef slope (Rs.)

Present Absent

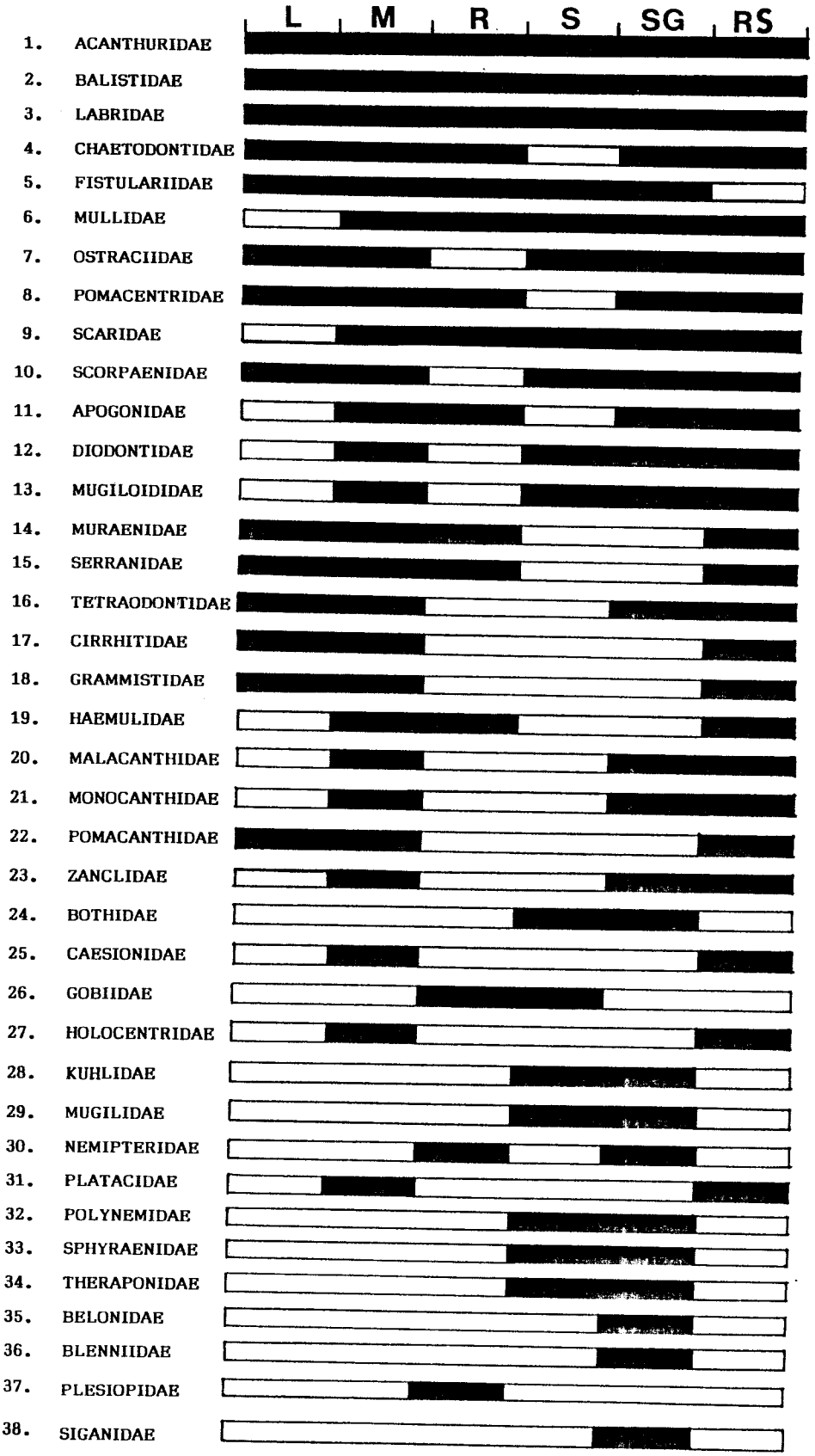


Table 15

Community diversity of the sub-habitats and the reef slope for families and species.

Sub-habitat	Family H'	Species H'
Live coral	1.84	3.16
Massive coral	2.96	3.93
Rubble	2.68	3.58
Sand flats	2.69	3.25
Seagrass beds	2.49	3.14
Reef slope	3.32	4.45

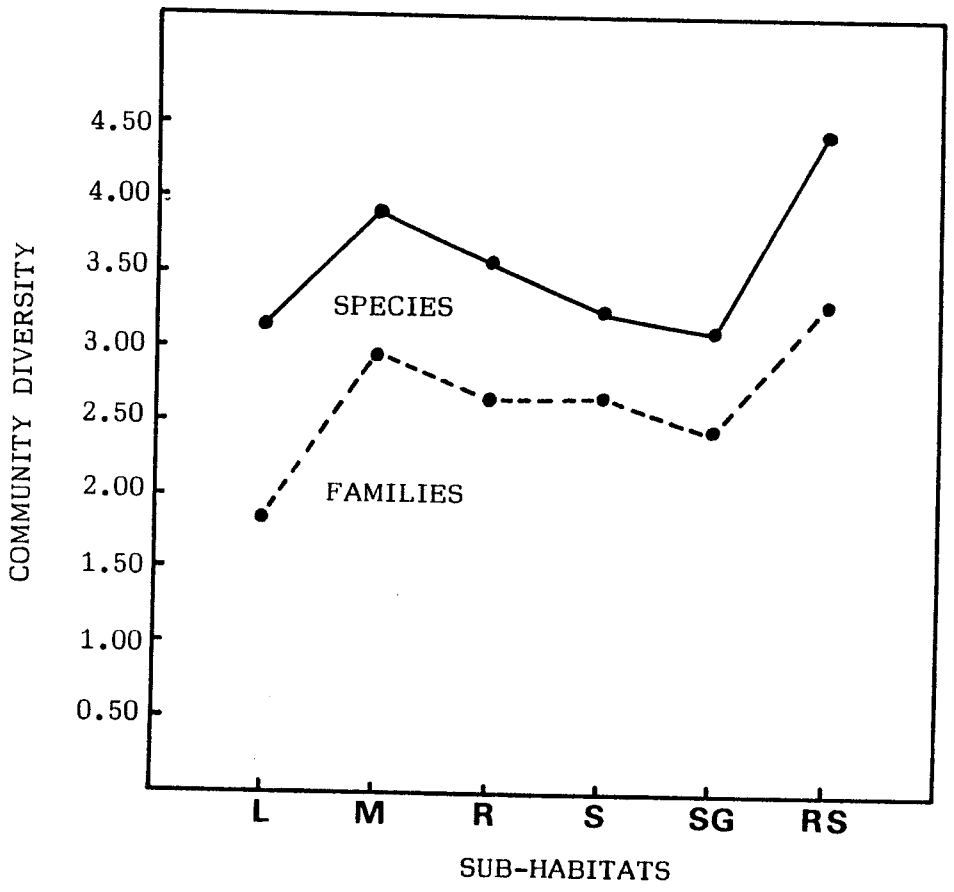


Figure 21. Community diversity (H') of fish families and species on the five sub-habitats - live coral (L), massive coral (M), rubble (R), sand (S) and seagrass (SG) and the reef slope (RS).

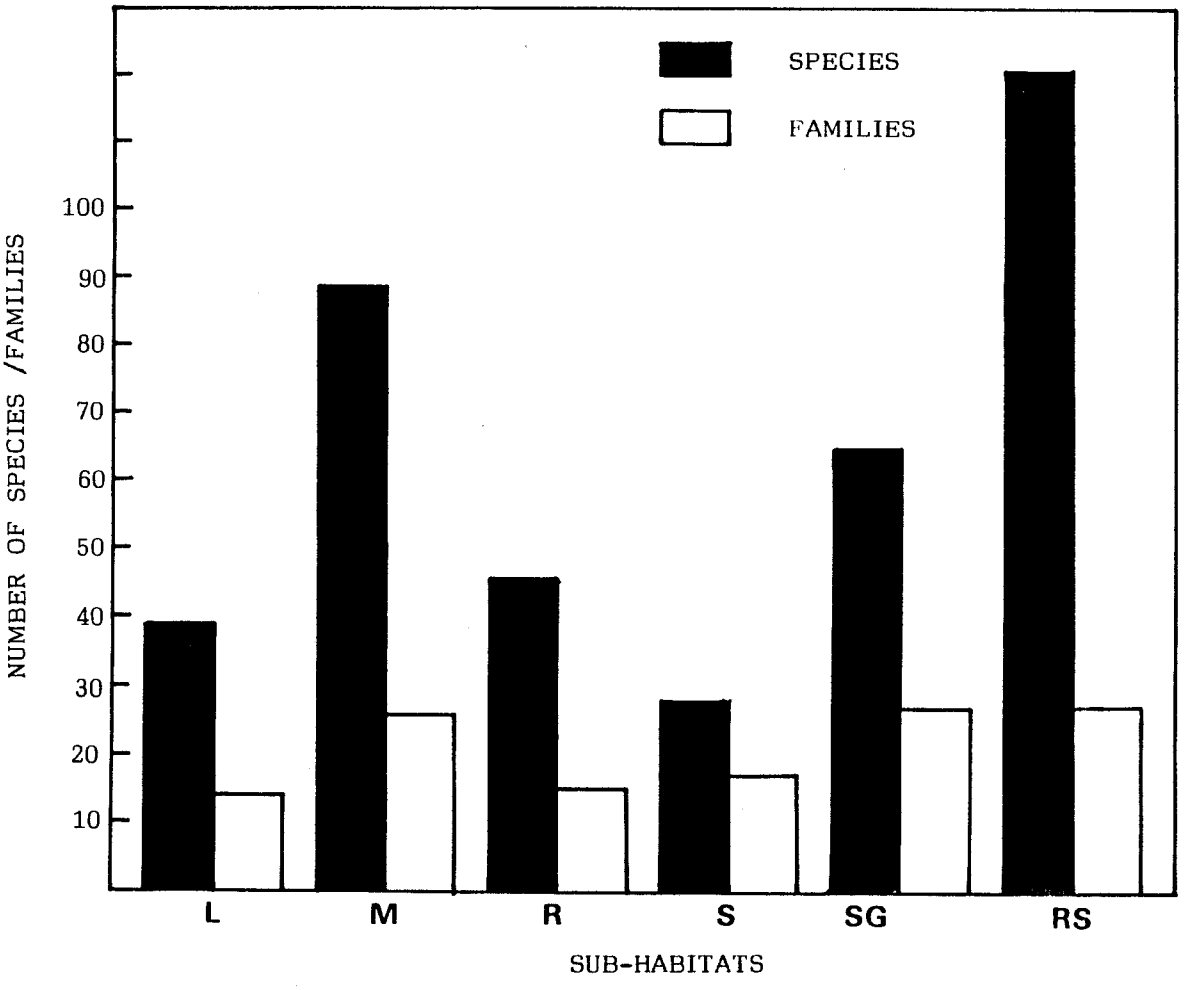


Figure 22. Total number of fish species/families recorded on the five sub-habitats - live coral (L), massive coral (M), rubble (R), sand (S) and seagrass beds (SG) and reef slope (RS).

recorded by massive coral zone amongst the sub-habitats (2.96). Diversity of rubble zone (2.68) was comparable to sand flats (2.69) while seagrass beds registered a value of 2.49. The live coral zone indicated lowest diversity of 1.84. The reef slope recorded the highest diversity of 3.32 (Fig. 21).

The reef slope and seagrass beds recorded the presence of 27 families each while the massive coral compared closely to these with 26 families. Live coral, rubble and sand flats recorded 14, 15 and 17 familie respectively (Fig. 22).

DISCUSSION

The ways in which many reef fish families inhabiting a particular sub-habitat are organised into communities, their patterns and changes through time and in space are discussed in the following account. It was considered that superspecific units like trophic classes, genera and in this case, families (taxonomic) may represent a type of solution to the problem of occupation of ecological space. Due to association of reef fishes with coral reefs many specializations in life styles are evident and as a result they exhibit precise habitat requirements (Smith, 1977). This preference reflects on the mode of feeding and sheltering spaces required by reef fishes.

Community parameters of families on sub-habitats and reef slope:

Live Coral: In the live coral zone, Pomacentridae (62%) was the most dominant family as ramose corals are the most preferred habitat. Their relationship with the sufrace area of live coral was given by Pillai et al. (1985). They were reported to be ramose corals dwellers (Hiatt and Strasburg, 1960; Roberston et al., 1981, Shpigel, 1982) with limited home ranges (Sale, 1971), and live in small groups; this resulted in greater counts during censuses. Like typical pomacentrid residents, a single resident species contributed to the abundance of Pomacanthidae (13%) among live coral. Apart from Pomacentridae and Pomacanthidae that were heavily represented by the diversity indices (H'), Chaetodontidae and Labridae were relatively not habitat specific. The association of chaetodontids to this habitat is perhaps primarily due to food requirement. Many species of chaetodontids have been regarded as obligate or facultative coral polyp feeders (Randall, 1974; Reese, 1977; 1981, Burgess, 1978; Anderson et al. 1981; Harmelin - Vivien and Bouchon Navaro, 1983).

Wood (1979) observed greatest number of butterflyfishes on shallow, actively growing reefs and Bouchon - Navaro (1981) stated that out of 19 species studied 10 were ubiquitous. Most of them were positively correlated with greater percentages of live coral cover (Adrim and Hutomo, 1989). Among these dominant families, Labridae consisted of greater number of vagile species, which move about in search of food. In the present investigation the labrids were found to have fed on sessile hard shelled prey, and such sessile prey occur in a wide range of sub-

habitats including open sand flats (Parrish and Zimmerman, 1977; Vacelet and Vasseur, 1977) which were prominent features around the live coral zone. Certain species of labrids were reported to be numerous where reefs are interspread with patches of sand excavating buried organisms for food (Hobson, 1974). It is also possible that certain spawning aggregations have been included in the censuses, and such group spawning was reported by Randall (1965).

Serranids and scorpaenids are carnivores and their presence beneath the ramose coral heads appears to be advantageous in procurement of prey which is readily available in the form of small pomacentrid fishes and other invertebrates. Association of serranids with coral shelter (Talbot, 1965) and occurrence of Epinephelus hexagonatus in shallow lagoonal reefs were observed by Randall and Brock (1960). Scorpaenids were considered as ambuish predators (Hobson, 1974). Lower representation of Cirrhitidae is perhaps due to the absence of tabuloid species of Acropora coral heads which they prefer to stay poised on. Acropora formosa is a ramose coral and does not provide support for resting but on the other hand provides shelter for fishes like pomacentrids. Certain hawlkfishes (Cirrhitidae) were observed on coral heads by Talbot (1965). High diversity of Pomacentridae (4.58) and Pomacanthidae (4.55) are primarily due to richness in numerical density while in Chaetodontidae (4.71) and Labridae (4.33), it is due to evenness in distribution. H' of less than 1.00 indicated rare occurrence of the family (Table 2).

Massive coral: A shift in the family position from Pomacentridae on live coral to Labridae on massive coral zone was evident and is related to a greater species diversity within the family and topographic complexity that can harbour abundant invertebrate food organisms. Labridae is one amongst the most diverse tropical marine fish families (Nelson, 1984) and have more species per genera and more genera per family (Ross, 1986). Jones and Kumaran (1980) reported 45 species of labrids from the Lakshadweep region. The inherent diversity in the family may be the prime reason for labrid abundance in any of the sub-habitats followed by the presence of preferred food organisms. Parrish (1987) stated that invertebrate fauna may be abundant where the habitat provides sufficient protective cover. Occurrence of a variety of labrid species around coral mounds was observed by Hiatt and Strasburg (1960). Walsh (1985) proposed that habitat structure had little effect on fish communities present during day and that community dynamics of reef fishes may be dependent on reef location. Labrid abundance in the present study can also be related to the proximity of massive coral zone to the outer reef slope. Passes that occur on the reef crest were observed to facilitate fish movements into the lagoon area. A high H' (4.58) is a resultant of high numerical dominance coupled with an even distribution.

High numerical density of Scaridae was due to the schooling nature of juveniles and sub-adults but not due to frequent occurrence. Low occurrences are perhaps due to the high mobility that scarids exhibit and it is possible that the group was not always included during

censuses. This is also supported by a relatively lower H' value (3.42). Scarids move over large areas (Bardach, 1958) and were observed to be associated with glomerate (massive) coral heads (Hiatt and Strasburg, 1960). Some scarids were found to form feeding schools (Horn, 1989) and such schools on Kavarathi atoll constituted sub-adults. Acanthuridae shared a similar feeding niche. Though they were numerically less significant, H' was high due to even distribution in censuses. Acanthuridae dominated the reef flat region (Bouchon-Navaro and Harmelin-Vivien, 1981) while they were abundant on reef flats or reef slopes (Russ, 1984 b). It is possible that acanthurids migrated into shallower areas (massive coral zone) close to reef crest and reef flat through the passes, to feed on algae and larger individuals remained in relatively deeper water.

Greater occurrences of chaetodontids (H' = 4.48) could be explained by their movements for food and their relation to topographic complexity which is significant in massive coral zones. Hobson (1974) and Findley and Findley (1989) observed certain species to be nocturnal; sheltering in dark places during day, while some species are obligate coral polyp feeders (Talbot, 1965; Randall, 1974; Reese, 1977; Anderson et al., 1981; Harmelin-Vivien and Bouchon-Navaro, 1983; Hourigan, 1989) and some are facultative coral feeders or omnivores (Harmelin-Vivien, 1988; Findley and Findley, 1989; Sano, 1989). Due to this variation in food habits and behaviour it is likely that non-coral feeders represented the family on massive coral zone.

As a well known fact, most planktivorous pomacentrids are associated with ramose corals (Low, 1971; Sale, 1971; Reese, 1978; Robertson et al., 1981; Shpigel, 1982; Waldner, 1987) while omnivorous pomacentrids are associated with rubble or other coral debris with algal mats (Horn, 1989). In the present investigation, a consistent occurrence (H' = 4.07) of pomacentrids was due to the presence of small Acropora patches that were supported by the massive coral Though insignificant, cirrhitids also exhibited the same habitat requirement. Mullids are basically benthic feeders associated with soft sediments (Randall, 1974, 1983; Grovhoug and Talbot, 1976; Kuile, 1989) and their occurrence noticed in the present study is correlated to the sandy interspaces between coral heads as their preferred habitat. Though rare in occurrence, mugiloidids were also observed on sand patches.

Abundance of balistids on massive coral was relatively low (H' = 3.92) perhaps due to the presence of other preferred habitats in the vicinity (e.g., rubble). They were observed on lagoonal patch reefs, rubble, sand (Grovhoug and Talbot, 1976) and around glomerate and ramose coral heads (Hiatt and Strasburg, 1960). Rare occurrences and low H' values in other families is probably due to their high mobility across sub-habitats. Among these, the numerical dominance of Caesionidae is due to schooling behaviour. Talbot (1965) stated that caesionids form a neritic group which visit the reef sporadically. Other nocturnal and cryptic species remained concealed in ledges and crevices and posed serious problems in visual censuses, under estimating their numbers.

Rubble: In terms of H', Labridae was constistently weighted (H' = 4.8) among all censuses conducted. Labrid species of exceptionally large body sizes did not frequent these zones while the medium sized individuals predominated. Their abundance and frequent occurrence on rubble can be related to food requirements and shelter. Labrids mainly feed on benthic invertebrates (Hiatt and Strasburg, 1960; Hobson, 1965; Goldman and Talbot, 1976; Vijay Anand and Varghese, 1992a) and according to Grovhoug and Talbot (1976) and Randall (1983) certain species are associated with rubble. Rubble formed an extensive and prominent feature on Lakshadweep atolls and sessile invertebrates that form forage base are particularly abundant on hard reef substrate (Parrish and Zimmerman, 1977; Vacelet and Vasseur, 1977). This food resource attracts labrid assemblages. The shelter component cannot be well explained as all censuses were taken during day. However, labrids observed in aquaria promptly burried themselves in the bottom provided. Labrids were considered as late risers after day break (Goldman and Talbot, 1976) while the resting habit of a labrid species by burrowing beneath the sandy bottom was observed by Kabasawa (1982) under artificial conditions.

Unlike Labridae and other families recorded from the rubble zone, pomacentridae was numerically dominant and H' value (4.47) is suggestive of an even distribution and consistent representation. Strong association for food (algae and demersal plankton) and shelter among rubble crevices made this family a permanent resident. As already mentioned earlier, the herbivore/omnivore pomacentrid guild characteristically inhabited the zone. Robertson et al. (1981) stated that

a territory of a damselfish contains a mass of coral from which the fish derives required substrate-based resources like shelter from predators, a nest site and food from a distinct mat of algae.

Balistidae frequently occurred in relatively fewer numbers but a high H' value (4.22) is due to their constant dependence on the site for food and the demersal nesting behaviour in rubble. Association of balistids with sandy rubble bottoms (Hiatt and Strasburg, 1960; Grovhoug and Talbot, 1976) and their omnivorous feeding habit were explained by Hobson (1974).

Among these three dominant families, Pomacentridae indicated strong site attachement habit while others were temporary visitors. The high numerical density of Scaridae is due to the schooling nature of sub-adults. Mullids using this habitat was also primarily due to abundant invertebrate fauna available as food. Chaetodontid habits and their possible relations with the habitats were discussed earlier (massive coral zone) and the groups representation can be due to the presence of omnivores on rubble zones. Certain species of chaetodontids are ubiquitous and forage on all kinds of habitats (Grovhoug and Talbot, 1976; Galzin, 1987).

Small gobiids, serranids and plesiopids are abundant but could not be easily spotted during censuses due to cryptic behaviour or a nocturnal habit. The fact that sub-adult serranids are abundant among rubble can be supported by an experience that fished out 20 individuals of Epinephelus hexagonatus in half an hour's time by hook and line.

Though individuals belonging to Plesiopidae and Serranidae seem to be underestimated, they perhaps share a similar status that pomacentrids exhibit. Typically, these three families are resident on rubble zones but limited to smaller individuals.

Sand flats: A high representation of Labridae and Mullidae is suggestive of intense habitat use. As sand flats do not possess any topographic complexity, the fish assemblages certainly depend on the region for foraging grounds. The occurrence of mullids in feeding aggregations on sand has been observed by Talbot (1965) and Randall (1967, 1983). Certain species were considered nocturnal while some were diurnal in activity and feed on sand-dwelling invertebrates (Hobson, 1965, 1974). Labrids were also reported to be frequently associated with sand flats (Randall, 1967, 1983) and feed on loose sediments (Martosewojo, 1989). Feeding aggregations consisting both of labrids and mullids were observed on Kavaratti atoll. A casual raking up of loose sediment was also found to attract a number of labrids. Such aggregations were also reported by Munro (1976), Aronson and Sanderson (1987) and Strand (1988). In the present investigation mullids did not occurr consistently ($H' = 3.73$) during all censuses as compared to Labridae ($H' = 4.45$) and Acanthuridae ($H' = 4.14$), the latter with relatively lower numerical density (Table 5).

Certain acanthurids dwell in shallow areas (Lythgoe, 1971) while some are generalists (Galzin, 1987 a). Acanthurids and scarids had higher number of species and individuals on reef crests and in lagoons (Russ, 1984 b) and in the present study, the juveniles, sub-adults and

occassionally adults grazing on algae were observed. According to the observations of Russ (1984 b), if acanthurids are abundant on shallow waters of reef crests and in lagoons (Lythgoe, 1971), their frequent occurrence on sand flats seems reasonable due to their position in the lagoon and proximity to reef crest on Kavaratti atoll. The only permanent residents in this zone were individuals belonging to Bothidae and Mugiloididae, but were probably underestimated visually due to their hiding habits.

Kuhlidae, Mugilidae, Polynemidae, Sphyraenidae and Theraponidae were generally fast moving and were not always present in the field of view but characteristically occurred on sand flats. Mugilidae has been referred to as a generalised detrivore that associated raher indifferentially with a variety of shallow habitats (Parrish, 1987) and sand flats (Hiatt and Strasburg, 1960; Grovhoug and Talbot, 1976). Sphyraenids were grouped as free swimming midwater and surface communities (Hiatt and Strasburg, 1960; Martosewojo, 1989) and are known to roam farther afield (Bardach, 1958). Other families having fast moving individuals share similar characteristic and therefore pose problems in estimating the numbers and species identity.

Seagrass beds: Labridae was a persistantly occurring family (H' = 4.44). Mullids also share similar food resources with labrids and were relatively consistent in occurrence as indicated by H' (4.21) and frequency of occurrence (22 times). Juveniles were dominant and the situation holds good for majority of families recorded on seagrass beds. Bell and

Pollard (1989) stated that at the family level, Labridae was one among the dominant families recorded on seagrass but they did not mention about Acanthuridae, Mullidae and Scaridae. The abundance and frequent occurrence of labrids and mullids perhaps is due to abundant resident plankton (Emery, 1968) and food in the form of infauna and invertebrate fauna, crustaceans, echinoderms, gastropods, polychaetes, sipunculids etc. (Den Hartog, 1979). During a short term study on juvenile fish on seagrass beds in the present investigation (Chapter V) fine meshed drag nets not only captured a variety of juveniles of fishes but also included diverse forms of crustaceans and demersal zooplankton at night. This probably forms a good food resource for juveniles and other temporary visitors.

The two dominant herbivorous families (Acanthuridae and Scaridae) were typically represented by juveniles and adults in equal proportions, the dependence being for food and shelter. A very large fraction of all reef herbivores in all oceanic regions are Acanthuridae and Scaridae with the former group dominant on Indo-Pacific Island reefs (Bouchon-Navaro and Harmelin-Vivien, 1981). Predominance of acanthurids was on shallow habitats while scarids occurred in deeper habitats (Bradbury and Goeden, 1974). Compared to acanthurids, the scarids moved over large areas (Bardach, 1958). Considering the above mentioned assemblages and behavioural characteristics, the dominance of Acanthuridae ($H' = 4.28$) over Scaridae ($H' = 4.21$) at Kavaratti atoll is satisfactorily explained.

Though numerically less significant, Chaetodontidae was well represented only by juveniles. Similar observations, where juvenile and sub-adults were greater in shallow water areas on coral reefs and seagrass beds were made by Clarke (1977) and Bouchon-Navaro (1981). Monocanthidae and Fistulariidae were moderately represented families (H' = 3.42 and 3.06 respectively) and appeared to be more attached to seagrass beds. Harmelin-Vivien and Bouchon (1976) observed fistulariids to be associated with seagrass beds while monacanthids were known to eat seagrass (Randall, 1965; Ogden and Zieman, 1977; Parrish, 1987). Bothidae and Mugiloididae inhabited the region due to the presence of soft bottom sediments with which they are associated. Diodontids, ostraciids and tetradontids occurred occassionally. Ogden and Zieman (1977) observed recruitment of juvenile diodontids onto seagrass beds and Hiatt and Strasburg (1960) stated that these groups consist of weak swimmers and prefer sheltered areas. These could be the probable reasons for their occurrence on seagrass beds. Other free swimming groups (e.g., Belonidae, Kuhlidae, Mugilidae, Malacanthidae, Polynemidae, Sphyraenidae and Theraponidae) that were observed on sand flats were also recorded from seagrass beds due to proximity of sub-habitats.

Reef slope: A direct comparison between reef slope and other habitats cannot be made owing to sampling variations in the former. H' was above 4.00 for Acanthuridae, Chaetodontidae, Labridae and Mullidae indicating a persistent status in the reef slope community. Acanhurids formed the bulk of the individuals on the reef slope. Many factors contribute to this organisation at the family level owing to varying habits involved.

Feeding categories include zooplanktivory (Hobson, 1974), detritus feeders (Jones, 1968) and browsers and grazers on various algae (Hiatt and Strasburg, 1960; Hobson, 1974; Robertson et al., 1979) and therefore distribution is likely to be affected by the availability of food. Kingford (1989) suggested that hydrobiology may influence the composition and abundance of zooplankton that in turn influences feeding of fish on reefs.

Russ (1984 b) found higher numbers of acanthurids on reef crests and in lagoons than that on reef flats or reef slopes. Observations in the present study were in accordance with those of Harmelin - Vivien (1984) who found acanthurids to be predominant on the outer slope. It is therefore evident that depth also plays an important role in structuring fish communities. Gosline (1965) observed that plant eating fishes are constrained to shallow depths of 0 to 6 m. Sheppard et al. (1992) correlated acanthurid and scarid occurrences to shallow zones as algal productivity is high. Another dominant herbivore group - Scaridae is expected to be dominant along with acanthurids (Horn, 1989) but in the present investigation they occurred less frequently and lower counts were due to solitary nature of larger individuals. The foraging range also effects censuses. Bardach (1958) observed acanthurids to be rather restricted while scarids moved over large areas.

The dominance of chaetodontids is due to extra representation of species exclusively found on the reef slope and to the already existing species on other sub-habitats. It is perhaps also due to a positive correlation between coral cover and number of chaetodontid species (Wood,

1979) Anderson et al., 1981; Reese, 1981; Harmelin-Vivien and Bouchon-Navaro, 1983; Adrim and Hutomo 1989). Labrid dominance was significant on all sub-habitats studied and the group occurred consistently on the reef slope (H' = 4.13) but seems to be overshadowed by the presence of the other dominant families. A high H' value (4.31) of mullids is correlated to the presence of sand pockets on the reef slope on Kavaratti atoll. Mullids were observed to be moderately abundant and feed close to the reef (Randall, 1968; Ogden and Zieman, 1977).

Pomacentrids were probably more numerous than acanthurids but were probably underestimated owing to counting problems encountered with schooling species and their strong site attachement. Dense populations of pomacentrids in upcurrent areas (Hamner et al., 1988) were found grouped near the edge of the reef, waiting for plankton to come to them (Reese, 1978). Other important reef slope dwellers were serranids and haemulids. Serranids are likely to be underestimated due to their cryptic nature. Larger predators were found to be rich on the lower coral slope of Tutia reef (Talbot, 1965), while haemulids had a wide foraging range (Parrish, 1987). Greater abundance of caesionids is due to a schooling nature. Other families are considered occassional or rare.

To summarise the fish family component on sub-habitats, it is evident that labrids emerged to be generalists found on all sub-habitats except for not dominating on live coral zone. Subsequently, positions were occupied by specific families characteristic of particular sub-

habitats, reflecting primarily the feeding mode, site attachement and other habits. With an exception on sand flats where only two families were dominant, 3 to 5 families occured frequently.

Among the sub-habitats, the number of families recorded on seagrass beds (27) was comparable to reef slope region (27) mainly because postlarvae, juveniles and sub-adults of most reef fishes used seagrass beds as nurseries. Juveniles of several species of fishes on nearby reefs were found to use seagrass beds as nurseries in Panama and Caribbean regions (Ogden and Zieman, 1977; Weinstein and Heck, 1979; Shulman, 1988; Bell and Pollard, 1989) while many less abundant reef species also forage on invertebrate fauna of seagrass beds (Harmelin-Vivien and Bouchon, 1976). Many reef fish treat reefs and seagrass beds as single habitats (Ogden and Zieman, 1977). A similar status of the massive coral zone is perhaps due to its proximity to reef slope and passes that interconnect the regions on Kavaratti atoll. As the live coral zone is composed of a single species of ramose coral (Acropora formosa) very few families (14) made use of the zone. A similar picture was evident on rubble zones (15 families). A relatively higher family composition on sand flats despite its featurelessness as compared to rubble and live coral was due to its proximity to seagrass beds from where individuals were observed to perform short-term migrations. Anderson et al. (1981) states that reef fish are not specialised and they overlap extensivey in food and habitat requirements. Community diversity (H') indicated a pattern similar to family composition on sub-habitats excepting that it was

not markedly different between rubble and sand flats perhaps due to their physically unstable nature that affects biological communities.

Seasonal variation in community parameters

Storms are known to be a major cause of physical disturbance on all shallow reefs (Ebling and Hixon 1991). The southwest monsoon is a regular predictable phenomenon on Lakshadweep atolls. Therefore, the stability of reef fish families on the sub-habitats and reef slope is thought to be influenced.

Live coral: The high variation in number of individuals encountered during pre-monsoon (includes 'summer months') and post-monsoon (includes 'winter months') is perhaps due to concidence with recruitment peaks. Similar observations were made by Talbot and Russel (1978) where they observed recruitment to be high in summer on One Tree Reef, Great Barrier Reef (September to May). Monsoon variation in counts was influenced by relatively turbid and rough waters. Jones (1991) also stated that disturbance may influence population after recruitment by increasing mortality or inducing movement to or from affected areas.

As patch reefs in the present study are shallow habitats, the magnitude of disturbance was probably more. However, strong site-attached families like pomacentrids and pomacanthids may not leave the site while other families having free moving individuals influence total counts. This could also be substantiated by a high variation in H' and J' values during monsoon indicating that total number was low coupled with an

uneven distribution. Fluctuations in H' and J' which were pronounced in pre-monsoon as compared to post-monsoon may be due to marked summer peaks in recruitment (Sale and Dybdahl, 1975; Coles and Tarr, 1990). A stable nature in total number of families but variation in total counts indicates migration of larger individuals to avoid disturbance, movement of new recruits onto patch reefs, and a site attached nature of inhabiting families.

Massive coral: With limitations in obtaining data during monsoon season, fish assemblages consisted of lower numbers. The proximity of massive coral zone to the reef crest would have created a greater monsoon impact on the region in leading the fish to take shelter in the nearby deeper reef slope region. In general, shallow parts of the reef comprise a stressful environment in which to live (Sheppard et al. 1992) and it is likely that this increase in places like Lakshadweep is due to monsoon conditions. Higher counts in other seasons and greater variations between censuses indicated the dynamic nature of massive coral zone is not only supporting some resident fish fauna but also transient fishes from the nearby reef flat and reef slope. Ogden and Quinn (1984) in discussing factors affecting migrations in fish state that precisely timed spawning aggregations and diel patterns involved with feeding draw fishes to particular locations from wide areas of reef. Aggregating reproductive behaviour was observed by Barlow (1975 a).

Rubble: Rubble zones were relatively more shallow than massive coral zones. The very fact that it is storm cast coral debris (Chapter I) and

its proximity to the reef crest, reef flat and reef slope make it an unstable habitat both physically and biologically. The physical unstability perhaps is due to major changes made by monsoon in redistribution of habitats and associated species. Such a phenomenon was observed on fish assemblages near Discovery Bay, Jamaica, where a hurricane was the disturbing factor (Kaufman, 1983). The biological changes could be due to inundation of algae due to siltation (Letourner et al., 1992) and death of other invertebrates. The process of habitat shift also alters a biological composition of the area (Walsh, 1983; Letourner et al. 1992). Higher counts of individuals and number of families during pre-monsoon is probably due to new recruits, spawning and feeding aggregations, and roving sub-adult herbivores. During post-monsoon, relatively lower counts were probably due to less pronounced recuitment peaks and delay in re-establishment/recolonization of fish communities after monsoon disturbance. H' and J' values roughly supported the community patterns observed.

Sand flats: Sand flats on Kavaratti atoll were relatively poor in resident fish fauna; most of them being non-resident types. Fluctuation in monsoon was due to a single sample that recorded 135 individuals consisting of sub-adult scarids. The pre-monsoon counts were high due to ingress of new recruits of acanthudis and scarids from the adjacent seagrass beds. Fish were observed to leave the seagrass beds and cross to nearby sand flats, perhaps for temperoary foraging. Variation in H' and J' values during monsoon and post-monsoon is due to lower representation by individuals in each family and this perhaps could be related to the

disturbance factor as seen in rubble zones. Sand is more influenced by monsoon current and waves, thus causing physical instability. Delay in recovery of algal cover on sparse rubble found on sand flats could limit herbivourous fish assemblages. Higher counts during pre-monsoon could be due to stabilized resources and summer peaks in recuitment on adjacent seagrass beds. Community structure of fish was unpredictable as sand flats do not offer shelter for fish. Fish families that are free swimming frequent the area and their mobility makes community structure unstable.

Seagrass beds: There is a greater abundance and diversity of fish fauna associated with seagrass which are associated for different lengths of time at different stages of their life history. They are also known to be particularly important as nurseries for fish (Bell and Pollard, 1989). Such observations were also made in the present investigation (Chapter V) and high counts of fish and respective families substantiate the fact. Ogden and Zieman (1977) suggest that this situation is observed because reef fish treat reefs and seagrass beds as a single habitat. Fluctuations in all community parameters during pre-monsoon and post-monsoon were perhaps due to recruitment peaks found in those seasons. This is also supported by observations made by Middleton et al. (1984) and the variation is also likely to be affected by several families that visit the zone but occur as adults on nearby reefs (Weinstein and Heck, 1979; Shulman, 1985b). The juveniles and sub-adults were observed to be temporary residents which leave seagrass beds after attaining adult characters. Recruitment peaks were perhaps lower in monsoon owing to unfavourable currents, thus yielding lower counts and variation in assemblages.

Reef slope: Due to the presence of many families and greater number of individuals within each family, community parameters on the reef slope varied considerably. In the pre-monsoon a particular census recorded 414 individuals as against a minimum of 169 individuals in the same season. As discussed earlier, this variation could result due to feeding and spawning aggregations, recruitment and inherent richness of the habitat. Ben-Tuvia et al. (1983) found highest species diversity, richness and standing crop on the fore reef in Gulf of Aqaba. Number of species and individuals on the mid-and outer-shelf reef were relatively more than that found inshore (Russ, 1983) and prominence of assemblages on outer slope or outer shelf reefs was observed by other subsequent workers (Harmelin - Vivien, 1984; Russ, 1984 a, b; Lewis and Wain-wright, 1985). Due to extremly rough conditions during monsoon, conducting censuses was difficult during peak monsoon in open sea conditions. The limited data suggest that variation in community parameters was not pronounced.

In contrast, high attributes in fish family assemblages during post-monsoon could probably be due to post-disturbance effects. Movement of fish from shallow habitats could accumulate on reef slopes which were relatively deeper and protected by high reefs. A habitat shift, reef flats devoid of fish and deeper areas with more fish aggregated to avoid storm impacts were observed by Walsh (1983).

Family assembages on the sub-habitats and reef slope were not stable between censuses and between months and seasons. Fish assemblages on coral reefs were observed to be loosely structured and lack high degree of stability (Sale, 1982), and equal distribution (Galzin, 1985).

Inherent behaviour of fish connected to modes of feeding, reproduction, shelter requirement, movements across zones on reefs played a major role in structuring assemblages. Habitat selection has been domonstrated by Williams (1980), Williams and Sale (1981) and Ecker (1988) discussed it as a possible determinant for zonation. Non-biological factors like habitat structure (sand, rubble etc.), proximity to species-rich areas and nurseries (reef slope, seagrass beds) and the southwest monsoon influenced community structure. Methods used to census the population also have limitations. Nevertheless, the picture provided by multiple samples approaches to reality to a certain degree.

Distribution of families: Labridae, Acanthuridae and Balistidae emerged as generalists probably due to food resource availability. This is supported by a high H' value that weighed their representation on the sub-habitats. Balistidae registered low values of distribution owing to localized representation on rubble (50.00%) indicating an uneven distribution (J' = 0.77). Scaridae and Pomacentridae were numerically dominant due to schooling nature with uneven distribution owing to specific habitat preferences by Scaridae (on seagrass) and Pomacentridae (on live coral and rubble). In general, these five families dominated habitats on Kavaratti atoll. A wider habitat distribution could be due to a generalised diet that increases the apparent evenness of resource distribution (Clarke, 1977) and also due to diversity of food habits found within a single family (Hiatt and Strasburg, 1960; Hobson, 1974). For example, within acanthurids there are algal grazers/browsers, detritus feeders, zooplankton feeders (Jones, 1968) while balistids are known to feed on algae,

zooplankton, benthic crustaceans (Hobson, 1974) and corals (Randall, 1974). Therefore, distribution of these food resources determines the habitat selection in some of these families. Of these, only Pomacentridae exhibits a strong site-attachment.

Among the two sub-habitats (live coral and massive coral) the chaetodontid abundance was greater on massive coral zone due to influx of individuals from the nearby reef slope, while the live coral patches were separated by considerable distance. Seagrass beds mainly acted as nurseries for certain chaetodontids. Some chaetodontids were reported to be relatively restricted in distribution among zones (Bouchon - Navaro, 1980, 1981; 1986; Adrim and Hutomo, 1989; Fowler, 1990) and their greatest number on actively growing reefs (Wood, 1979). The occurrence of mullids was primarily dictated by the presence of soft bottom sediments that harbour preferred food organisms. Apart from sand flats, the interstitial sand patches between massive coral heads, rubble and seagrass explain their pressence on other habitats.

Among the two carnivores (Scorpaenidae and Serranidae) a higher representation of Scorpaenidae on live coral bases could be due to abundant, resident food resource consisting of small pomacentrids and coral dwelling invertebrates. Serranids used this zone but not to the extent found on massive coral zones. Underwater observations indicated a greater hunting capacity in serranids which could chase prey among massive coral, while scorpaenids in contrast were sluggish and perhaps depend on easily obtainable prey from a readily available resource. Serranids were also

collected from seagrass beds but visual censuses did not record individuals due to their cryptic nature. The distribution of serranids and lutjanids was observed to be stratified (Forster, 1984). Talbot (1965) found that the distribution of larger predators (serranids) becomes spatially very uneven compared to greater bulk of smaller species.

Six families had a moderate distribution on sub-habitats (Grammistidae, Malacanthidae, Muraenidae, Ostraciidae, Tetraodontidae and Zanclidae). Among these, Muraenidae was most site-attached on rubble, their distribution mostly governed by requirements of food and shelter. Certain species of teraodontids fed on live coral and ostraciids, with weak swimming capacity, take shelter between coral heads and feed on polychaetes from sand (Hiatt and Strasburg, 1960). This behaviour is perhaps related to the occurrence of tetraodontids and ostraciids on respective habitats in the present investigation. Muraenids are ambuish predetors and require shelter to take their prey by surprise. Larger individuals took shelter beneath live coral bases and massive coral, while juveniles occurred on rubble zones. Due to rare occurrence of a single species belonging to Grammistidae, conclusive interpretations are not possible. However, they seem to be associated to habitats with sufficient topographic complexity. Malacanthids (rare) and zanclids were relatively free swimming and seem to inhabit massive coral and seagrass for food.

Certain families exhibited narrow habitat requirement. Cirrhitidae was always associated with tabular Acorpora heads and this observation is in agreement with that of Talbot (1965). Though diodontids occurred in

other habitats, they were prominent on seagrass beds prefering quiet waters (Hiatt and Strasburg, 1960) and in the present study seagrass beds were found to be flourishing in calm lagoons. Further, Ogden and Zieman (1977) found diodontids recruiting onto seagrass beds. Occurrence of fistulariids on certain habitats could be considered accidental but they were specific seagrass dwellers. This was also observed by Harmelin-Vivien and Bouchon (1976). Haemulid species were not diverse in Lakshadweep. However, certain species were observed to form large schools on the reef slope. Their occurrence on the massive coral is probably due to proximity of the zone to the reef slope.

Haemulids were reported to be nocturnal and feed on seagrass beds at night and rest over coral heads by day (Meyer et al., 1983). In view of this behaviour the group might have been underestimated. A similar trend was also noticed for apogonids and holocentrids. Though supporting numerical data are sparse, these nocturnal groups are amongst the diverse groups on reefs of Lakshadweep (Chapter VI on fishing methods). Like fistulariids, Monacanthidae had exclusive seagrass bed dwellers. Bell and Pollard (1989) reported Monacanthidae as one among the dominant 6 families occurring on seagrass beds in almost 25 geographic localities studied. According to their list, other families that matched in abundance on Kavaratti atoll were Labridae and Scorpaenidae. Mugiloidids were the only permanent inhabitants on sand flats that used it for food and shelter. Pomacanthidae recorded a narrow habitat width owing to a single territoral, ramose coral dwelling species. Other species were found in relatively deeper waters (reef slope) and hence were not recorded on other sub-habitats.

A much narrower habitat breadth was found in Belonidae, Nemipteridae, Plesiopidae and Siganidae. Belonids are generally free swimming and were observed on other habitats at night but were found only on seagrass beds during censuses. Martosewojo (1989) found certain nemipterids to prefer deeper reef habitats (reef edge) in which case their rare occurrence in shallow sub-habitats is justified. Plesiopids were observed to be nocturnal and their inclusion during day time censuses may not be realistic but their absence on other habitats indicates that they are habitat specific (on rubble). Siganids were recorded only once during censuses and perhaps move over larger areas. Casual fishing observations indicated sudden massive summer recruitments of siganids.

A few groups (except Bothidae) cannot be considered as true inhabitants of sand and seagrass as they are neretic free swimming forms (Caesionidae, Kuhlidae, Mugilidae, Polynemidae, Sphyraenidae and Theraponidae). Platacidae is also constrained by depth limitations while cryptic species like blenniids and gobiids would have been underestimated. Blenniids are poorly quantified in almost all localities but it is likely that they are of comparable importance (Parrish, 1987).

High H' values indicated a wider habitat width and this resulted from greater individuals in each sub-habitat and their evenness of distribution. Least H' & J' values (0.00) indicated a specific nature of the family to the particular habitat. Resource partitioning studies serve an important practical need in providing information on habitat requirements

of fishes (Ross, 1986). At the family level, habitats were widely inhabited by certain families, while some were restricted in distribution. This primarily seems to reflect modes of feeding, morphology, behaviour and other life styles of coral reef fish.

Considering the presence/absence of families on the sub-habitats, most families recorded on the reef-slope were found on the sub-habitats. Certain families like Fistularidae, Bothidae, Plesiopidae and Theraponidae seem to prefer shallow water probably due to their small body size and specific habitat requirements, while larger adults of certain pelagic and epibenthic families (Sphyraenidae and Polynemidae) were not recorded during censuses but certainly inhabit deeper water. From Fig. 20, it is evident that a similarity of families between reef slope and massive coral and to an extent seagrass beds exists. The former situation could be due to proximity between the zones while the latter could result due to utilization of seagrass beds as nurseries or feeding grounds for almost all families of reef fish. This also supports the ideas of Ogden and Zieman (1977) who stated that many reef fishes treat reef and seagrass beds as single habitats.

B. SPECIES

1. Community parameters on sub-habitats and reef slope:

   a. Live Coral: Table 16 depicts the community parameters of 39 species recorded from the live coral zone. A single species belonging to Acanthuridae, Acanthurus leucosternon occurred in the

sub-habitat. Of the two balistid species observed, Balistoides viridescens was recorded 14 times with a total of 35 counts (1.31%) accounting for a relatively high sample diversity (3.44). Nine chaetodontid species were found to frequent live coral zones, of which the commonly occurring (24 times) and relatively abundant (123 nos) species was Chaetodon auriga (4.61%) with a high diversity of 4.42. This was followed by Chaetodon xanthocephalus (1.65%) with a diversity of 3.26. Among the three rare species accounting for diversities of 2.27, 2.10 and 2.27 (C. trifascialis, C. trifasciatus and C. vagabundus), C. trifasciatus was numerically dominant (19 nos). Least counts were recorded by Chaetodon falcula and C. citrinellus (7 nos each), the latter recording the least diversity (0.98).

Paracirrhites forsteri appeared 7 times with a relatively high diversity of 2.68, while Fistularia petimba and Grammistes sexlineatus were recorded only once.

Among the 7 labrids recorded, Halichoeres scapularis was found more frequently (21 times) and dominated on live coral (141 nos). Accounting for a high diversity (4.21) it formed 5.29% of the fish recorded from the sub-habitat. Halichoeres centiquadrus and Thalassoma hardwicki also occurred in relatively high numbers (25 and 40 individuals respectively). Other species recorded were, however, rare with low proportions of 0.04 to 0.15%. Gymnothorax undulatus occassionally occurred (6 times) while Lactoria cornuta and Ostracion meleagris were rare (2 times).

A single species belonging to Pomacanthidae, Centropyge multispinis contributed significantly to numerical density (348 nos) on live coral forming 14.4% of fish recorded. Diversity in C. multispinis was high (4.55). Two pomacentrid species, namely, Dascyllus aruanus (657 nos) and Chromis caerulea (579 nos) were dominant contributing to 24.64% and 21.69% with diversities of 4.46 and 4.40 respectively. Dascyllus trimaculatus (172) and D. reticulatus (133 nos) contributed to 6.45 and 4.99% with diversities of 3.80 and 3.62 respectively. Abudefduf sexfasciatus was occasionally present (3.34%) while the other species together contributed to less than 0.50%.

A total of 59 individuals of Epinephelus spp. forming 2.21% were recorded with a diversity of 3.82. Cephalopholis argus was present only 4 times. Dendrochirus zebra was commonly present in the live coral zone recording 33 individuals (1.24%) and a diversity of 3.47. Pterois radiata was recorded only once. Tetraodon nigropunctatus was encountered on 5 instances (23 nos).

b. Massive coral: Table 17 depicts the community parameters of 89 species found on the massive coral zone. Acanthurus leucosternon (153 nos) was abundant among the 8 acanthurid species recorded, contributing to 3.96% of the fish recorded with a diversity of 4.10. This was followed by A. triostegus with 88 individuals (2.28%) with a diversity of 2.96. Acanthurus spp. and A. lineatus were common, with 70 and 51 individuals (1.81 and 1.32%)

recording diversities of 2.83 and 2.57 respectively. Zebrasoma veliferum and three species belonging to the genus Naso were rare (below 0.10%). Naso lituratus had a relatively high diversity (1.59) among the three.

Caesionids and apogonids were recorded 2 and 3 times with 200 and 53 individuals respectively. Of the two, caesionids contributed to 5.18% but with a lower diversity (1.00) while apogonids recorded 1.39. The commonly occurring balistid was Rhinecanthus aculeatus (51 nos contributing 1.32%) with a diversity of 3.84. Melichthys indicus, Rhinecanthus rectangulus, and Sufflamen bursa were rare in occurrence (1 to 4 times). Of the three species, 15 individuals (0.39%) of M. indicus were recorded.

11 species belonging to Chaetodontidae were found (Table 16). Chaetodon auriga (154 nos) was most abundant, composing 3.98% and a high diversity of 4.47. C. citrinellus was encountered 11 times with 26 individuals (0.67%) which was relatively lower when compared to 40 individuals (1.04%) recorded by C. collare. Their diversity values were 3.36 and 2.12 respectively. C. trifasciatus yielded a similar diversity (2.53) though it recorded only 15 nos. on the sub-habitat. Occurring relatively more in number (17 nos) was Heniochus acuminatus. Excluding C. auriga and C. collare all other species contributed to proportions lower than 0.70%. C. lunula, C. kleinii, C. melannotus and Heniochus monoceros occurred only once or twice on the sub-habitat.

Six individuals of Paracirrhites forsteri were found on four occassions. Cirrhites, pinnulatus, Diodon histrix and Fistularia petimba were found only once contributing to low percentages. Solitary presence of Grammistes sexlineatus was recorded three times. Of the two species of haemulids, Plectorhinchus orientalis (11 nos) had a diversity of 2.65 while P. gibbosus was ecountered only twice. The three holocentrid species appeared rarely (2 to 3 times) of which Sargocentron spp. recorded 16 individuals.

Twenty three labrid species were found on massive coral zones. Halichoeres centiquadrus (270 nos) occurred on 22 occassions, contributing to 6.98% and a diversity of 4.27. This was followed by H. scapularis with a relatively high diversity of 4.04, accounting to 199 individuals (5.14%). Labroides dimidiatus also commonly occurred (17 times) with 105 nos. Both, Thalassoma hardwicki and Cheilinus undulatus accounted for 70 nos (1.81%) and diversities of 3.36 and 3.32 respectively. Other species occassionally occurred (3 to 11 times) each contributing to less than 1%. Bodianus axillaris, Hemigymnus melapterus, Stethojulis strigiventer, Halichoeres nebulosus, Labroides bicolor, Thalassoma herbraicum and T. purpureum occurred only once or twice. Of these, only S. strigiventer recorded 13 individuals.

Ganthodentex aureolineatus was observed to have high number (300 nos) forming 7.76% though encountered only thrice. Monotaxis

grandoculis, Malacanthus latovittatus and Alutera scripta were found only 1 to 3 times resulting in low proportion and diversities. 17 individuals of Parapercis hexophthalma were found in 5 samples. Among the 6 mullids, high sample diversities of 3.15 and 3.10 were recorded by Parupeneus barberinus (84 nos) and P. macronema (56 nos) contributing to 2.16 and 1.45% respectively. This was followed by P. bifasciatus (37 nos) with a diversity of 2.98. Though Mulloides flavolineatus was found only twice, 30 individuals were recorded. P. cyclostomus and P. pleurostigma represented the habitat in fewer numbers (6 and 9 respectively).

Echinda nebulosa and Gymnothorax undulatus appeared only once. Similarly a single pomacanthid species, Centropyge multispinis occurred once but with 18 individuals. Platax orbicularis and Lactoria cornuta occurred 2 and 3 times respectively.

Of the 7 species of pomacentrids, Abudefduf sexfasciatus was most dominant (112 nos) contributing to 2.90% with a diversity of 3.75. Though Chrysiptera biocellata was found only 6 times (13 nos) it recorded a diversity of 2.52. Pomacentrus trilineatus was encountered two times but with 104 individuals, diversity being low (0.23). Chromis caerulea occurred only thrice with 49 individuals, while Amphiprion nigripes numbering 19 were counted from anemones, on 4 occassions. Pomacentrus pavo and Plectroglyphidodon phoenixensis were rare.

Scarus spp. accounted for the highest number (881 nos) on the habitat, contributing to 22.80% with a diversity of 3.34. Of the two species of scorpaenids, Pterois miles (7 nos) was common, accounting to a relatively high diversity (2.52), while P. radiata was found only twice. 66 individuals of Epinephelus spp. were found with a diversity of 3.32, while Cephalopholis argus recorded 22 individuals. 23 individuals of Canthigaster margaritata were found around massive coral. While Tetraodon nigropunctatus was rare (Table 16), Zanclus canescens occurred 7 times accounting for 29 individuals and a relatively high diversity (2.59).

c. Rubble: Table 18 depicts community parameters of 46 species recorded from the habitat. Of the five acanthurids found on rubble, Acanthurus triostegus was dominant (132 nos) contributing to 4.43% with a diversity of 3.68. This was followed by Acanthurus spp. with 43 individuals. Other species were however rare. A single apogonid, Apogon fraenatus occurred once.

Rhinecanthus aculeatus accounted for 116 individuals and occurred commonly (21 times) with a diversity of 4.18. Other two balistid species, Melichthys indicus and Rhinecanthus rectangulus were found only 5 times together forming less than 1%. Of the two chaetodontid species, Chaetodon citrinellus appeared 8 times accounting for 30 individuals while Chaetodon auriga was observed only once. 6 individuals of Fistularia petimba were recorded, while gobiids were dominant (111 nos) on rubble with a diversity of 3.11. Plectorhinchus orientalis occurred only thrice.

Of the 13 labrid species recorded among which Halichoeres scapularis dominated (384 nos) with a high diversity of 4.45 contributing to 12.89% of fishes recorded, appearing 2 times. Stethojulis albovittata, Halichoeres nebulosus, H. centiquadrus, Labroides dimidiatus and Cheilinus trilobatus occurred in relatively moderate numbers (16 to 49 nos) but less frequently with diversities ranging from 1.94 to 2.48. Other species were rare, occurring once or twice, recording low proportions, except Cheilinus undulatus that occurred 4 times (10 nos).

Of the 4 species of mullids, Parupeneus barberinus and P. bifasciatus were common (8 to 10 times) accounting for 66 and 38 individuals respectively. P. barberinus contributed to 2.22% of the fishes with a diversity of 3.19. Mulloides flavolineatus and P. pleurostigma accounted for less than 0.70% with least diversity (1.30).

Gymnothorax undulatus, Scolopsis bilineatus and Plesiops caeruleolineatus were single representatives of their respective families, the latter accounting for 31 individuals (1.04%) while in the former two species, 11 and 26 individuals were recorded.

Chrysiptera biocellata, Pomacentrus pavo, and P. trilineatus were the most abundant pomacentrids on rubble with 305, 285 and 202 individuals contributing to 10.24, 9.57 and 6.78% respectively. Though P. sulfureus recorded only 117 nos., it had a diversity of 4.09 which was comparable to diversities (4.12 to 4.38) recorded

by the species mentioned above. Plectroglyphidodon phoenixensis indicated a diversity of 3.49 with 109 individuals. Occurrence of Stegastes nigricans and Pomacentrus spp. were low (2 to 3 times) with 15 to 25 individuals. Abudefduf sexlineatus, Dascyllus aruanus and Stegastes lividus were found only once.

Scarus spp. accounted for the highest abundance of 620 individuals (20.82%). A single serranid, Epinephelus spp. recorded 19 counts.

d. Sand flats: Table 19 depicts the community parameters of 28 species found on sand flats. 14 families were represented by single species. Amongst these species, Rhinecanthus aculeatus, Bothus pantherinus, Diodon histrix, Fistularia petimba, Ganthodentex aurilineatus, Lactoria cornuta and gobiids, had percentages below 0.50, while the same in Trachinotus spp. (16 nos), Kuhlia mugil (39 nos), Crenemugil crenilabis (26 nos), Polynemus spp. (25 nos) Sphyraena spp. (31 nos) and Therapon jarbua (36 nos) mostly ranged between 1.23 to 3.00, except in Parapercis hexophthalma (51 nos) where it was 3.92. Most of the species listed above occurred 1 to 7 times except Therapon jarbua, Polynemus spp., and P. hexophthalma which occurred 8, 9 and 14 times respectively.

Acanthuridae and Scorpaenidae recorded the presence of two species each. Acanthurus triostegus (172 nos) contributed to 13.22% with a diversity of 4.06 while A. leucosternon contributed

only to 0.46%, occurring twice. Of the two species of scorpionfishes, Dendrochirus spp. recorded 12 individuals, and occurred 5 times, while 4 individuals of Pterois miles occurred 4 times.

Four species of labrids and 5 species of mullids were recorded from the sub-habitat. Among the labrids and other fishes, Halichoeres scapularis showed high density (356 nos) contributing to 27.36%, with a diversity of 4.43. Stethojulis albovittata, Cheilio inermis and Thalassoma hardwicki occurred 2 to 8 times with 5 to 28 individuals. Amongst mullids, Parupeneus barberinus (132 nos) occurred 18 times contributing to 10.15% with a diversity of 3.92, while P. macronema accounted for only 54 individuals (4.15%) with a diversity of 3.05. Mulloides flavolineatus was observed 6 times, recording 41 individuals (3.15%) while in P. bifasciatus it was 23 individuals (1.77%). P. pleurostigma appeared only once.

Scarus spp. occurred only 5 times but contributed significantly to the sub-habitat accounting for 15.84% (206 nos) and a low diversity of 1.20.

e. Seagrass beds: Table 20 depicts the community parameters of 65 different species found on the sub-habitat. Acanthurus spp. recorded 111 individuals (2.69%) though it was present 15 times, while Acanthurus triostegus (173 nos) occurred 14 times contributing to 4.20%. The diversity values were 3.35 and 3.65

respectively. Zebrasoma veliferum (21 nos), Acanthurus leucostermon (14 nos) and Naso unicornis (22 nos) appeared 6 to 9 times with proportions and diversities ranging between 0.34 and 0.53% and 2.26 and 2.89% respectively.

Two species of apogonids, Apogon fraenatus (8 nos) and A. taeniophorus (6 nos) occurred only once. Balistoides viridescens (8 nos) and Pseudobalistes flavimarginatus (12 nos) were found 4 and 3 times respectively. (Table 19). Tylosurus spp. and Omobranchus spp. appeared 4 times recording 38 and 42 individuals respectively.

Amongst 8 species of chaetodontids, Chaetodon auriga was recorded 18 times (101 nos) contributing to 2.45% of fishes recorded with a diversity of 3.94. C. melannotus (31 nos) C. xanthocephalus (33 nos) and Heniochus acuminatus (25 nos) showed diversity values of 3.00, 2.12 and 2.70 respectively, accounting to less than 1%. Other species occurred only once with individuals ranging from 2 to 5 times contributing to less than 0.05% in each case except C. trifasciatus which contributed to 0.12%.

Diodon histrix (17 nos), Fistularia petimba (149 nos) Kuhlia mugil (143 nos), Monotaxis grandoculis (4 nos) and Malacanthus latovittatus (one) were single species representing respective families. Of these, F. petimba and K. mugil accounted for significant numbers on the habitat contributing to 3.61 and 3.48% respectively.

Fourteen labrid species were recorded. Halichoeres scapularis (332 nos) abundantly occurred (20 times) forming 8.05% of fishes recorded, with a diversity of 3.75. Stethojulis albovittata (167 nos) and S. strigiventer (183 nos) were conspicious on seagrass beds forming 4.05 and 4.44% accounting for diversities of 3.85 and 3.49 respectively. Cheilio inermis (84 nos) was recorded 15 times, accounting to 2.04% with a diversity of 3.52. All other species recorded formed percentages less than 0.50%. Of these Coris gaimard, Hologymnosus doliatus and Anampses caeruleopunctatus recorded 18, 13 and 9 individuals respectively.

Alutera scripta (28 nos) was common on seagrass beds occurring 11 times with a diversity of 3.35. Cantherinus pardalis, Crenemugil crenilabis and Parapercis hexophthalma were found 2 to 4 times with either 5 or 6 individuals. Of the 6 species of mullids recorded, Parupeneus macronema (81 nos), Mulloides flavolineatus (115 nos). P. barberinus (69 nos) were common with diversities of 3.50, 3.45 and 3.25 accounting to 1.97, 2.79 and 1.67% respectively. Though Parupeneus bifasciatus and P. pleurostigma occurred only 7 and 9 times, they recorded 52 and 36 individuals respectively. P. cyclostomus occurred only once.

Scolopsis bilineatus and Ostracion meleagris were encountered only once while Lactoria cornuta was found twice. All three species registered low percentages. 19 individuals represented the genus Polynemus, thrice. A single species of pomacentrid, Abudefduf sexfasciatus (40 nos) occurred 8 times. Scarids were the

most abundant group (1752 nos) on seagrass beds forming 42.50% of the fishes recorded with a diversity of 4.21. Scorpaenidae and Tetradontidae recorded the presence of 2 species each. Of these, Pterois miles (15 nos) was found 7 times while Tetraodon nigropunctatus occurred 5 times. Dendrochirus zebra and Canthigaster margaritata were rare. Siganus stellatus (2 nos), Sphyraena spp. (38 nos), Therapon jarbua (4 nos) and Zanculus canescens (19 nos) were single species that represented respective families.

f. Reef slope: Table 21 depicts the community parameters of 121 species recorded from this region. Of the 9 species of acanthurids recorded, Acanthurus spp. (411 nos) formed 6.50% of fishes recorded with a diversity of 4.00. Acanthurus leucosternon (299 nos) A. lineatus (210 nos) and Naso unicornis (163 nos) occurred 13 to 17 times forming 4.73, 3.32 and 2.58% and diversities of 3.55, 3.45 and 3.35 respectively. Other species occurred 2 to 8 times with total counts and proportions between 19 to 34 and 0.30 to 0.54 respectively. Of these Zebrasoma veliferum and Naso lituratus had diversities of 2.41 and 2.45.

On 3 occassions a total of 76 apogonids were recorded. 11 species of balistids were found on the reef flat region. Melichthys indicus (168 nos), Odonus niger (131 nos) and Rhinecanthus aculeatus (72 nos) commonly occurred 11 to 13 times. M. indicus showed a diversity of 4.52 while O. niger and R.

aculeatus registered values of 3.34 and 3.27 respectively. Other species were rare in occurrence (1 to 7 times) accounting for percentages less than 1. Of these, Balistapus undulatus (22 nos) and Balistoides viridescens (33 nos) were relatively more in number.

A total of 159 caesionids and a single species of carangid, Elagatis pinnulatus (6 nos) were recorded 5 times.

A total of 18 chaetodontid species were found on the reef slope. In terms of numerical abundance, Chaetodon collare (148 nos), Hemitaurichthys zoster (134 nos) and Chaetodon auriga (103 nos) ranked relatively high and occurred 13, 7 and 17 times with percentages of 2.34, 2.12 and 1.63 respectively. High diversities were recorded by C. auriga (3.78), C. collare (3.52) and Forcipiger spp. (3.02), though the latter recorded only 17 individuals occurring 10 times. Other species appeared 1 to 7 times with percentages below 0.75. Among these Heniochus acuminatus accounted for 46 individuals followed by 24 and 17 individuals in Chaetodon xanthocephalus and C. citrinellus. C. plebeius, C. lunula, C. triangulum, C. melannotus and Heniochus monoceros were rare.

Paracirrhites forsteri (53 nos) occurred 10 times registering a low diversity of 2.91, while Cirrhites pinnulatus recorded only 4 individuals. Diodon histrix (3 nos) and Grammistes sexlinentus (9 nos) were found in 2 and 6 samples respectively. Two

haemulid species, Plectorhinchus orientalis (14 nos) and P. gibbosus (83 nos) were recorded, where the latter occurred only 5 times. Of the two, P. orientalis had a highest diversity of 3.03. Three species of holocentrids were found on the reef slope of which Sargocentron spp. (14 nos) dominated followed by Myripristis murdjan (11 nos) occurring, 3 times; Myripristis adusta occurred twice.

Of the 24 labrids recorded Halichoeres scapularis (299 nos) was abundant occurring 17 times, forming 4.73% of fishes recorded with diversity of 3.55. Other species with diversities above 3.00 were Thalassoma hardwicki (142 nos), T. lunare (88 nos) Halichoeres centiquadrus (162 nos) and Cheilinus undulatus (50 nos) occurring 10 to 14 times. Labroides dimidiatus accounted for 46 individuals but with a relatively low diversity of 2.43. Gomphosus varius (24 nos), G. coeruleus (14 nos), Thalassoma herbraicum (14 nos), Cheilinus trilobutus (35 nos), Coris gaimard (7 nos) Halichoeres nebulosus (19 nos), H. marginatus (17 nos) and Novaculichthys taeniourus (14 nos) were less common, each accounting for a percentage less than 0.60, occurring 4 to 7 times. Other species were rare and were recorded only once or twice.

Monotaxis grandoculis (5 nos), Gnathodentex aureolineatus (6 nos) Lobotes surinamensis (one) Aprion viriscers (3 nos), Malacanthus latovittatus (2 nos) Cantherines pardalis (7 nos) and Alutera scripta (one), occurred 1 to 3 times while Parapersis hexophthalma occurred 6 times, recording 35 individuals.

Of the 6 mullids recorded, Parupeneus barberinus (101 nos) and P. bifasciatus (80 nos) were relatively more, occurring 12 and 11 times respectively while the other four species occurred 2 to 4 times. 6 individuals of P. cyclostomus were recorded twice.

Echinda zebra (2 nos) Gymnothorax undulatus, Gymnothorax spp. (one each) and Scolopsis bilineatus (8 nos) occurred only once or twice. Two species of ostraciids were recorded with counts of 6 and 8 respectively. Platax orbicularis occurred 4 times accounting for 12 individuals. Pomacanthids were also rare and were encountered 1 to 4 times with 1 to 8 individuals. Among these, the most frequent species was Pomacanthus imperator (4 times) accounting for diversity of 2.24 while Pygoplites diacanthus was found only once.

Ten species of pomacentrids were found. Chrysiptera biocellata occurred more frequently (11 times) followed by Abudefduf sexfasciatus (9 times) and Chromis caerulea (8 times) forming 3.97, 1.27 and 6.41% respectively. In terms of numerical density C. caerulea accounted for 405 individuals followed by 251 in Chrysiptera biocellata, 189 in Dascyllus aruanus and 112 in D. reticulatus. A diversity of 3.03 was registered by Abudefduf sexfasciatus but only 80 individuals were recorded. Pomacentrus spp. (92 nos) and Dascyllus trimaculatus (33 nos) were less common (5 times). Amphiprion nigripes (10 nos), Chromis dimidiatus (4 nos) and Plectroglyphidodon phoenixensis (8 nos) occurred once or twice.

Table 16 to 21. Frequency of occurrence (FO), total abundance (TA), percentage abundance (%) and diversity index (H') for each fish species recorded on the five sub-habitats and reef slope. (January 1991 to June 1992)

Table 16

LIVE CORAL

SPECIES	FO	TA	%	H'
ACANTHURIDAE				
Acanthurus leucosternon	1	1	0.04	0.00
BALISTIDAE				
Balistoides viridescens	14	35	1.31	3.44
Rhinecanthus aculeatus	4	5	0.19	1.91
CHAETODONTIDAE				
Chaetodon auriga	24	123	4.61	4.42
Chaetodon xanthocephalus	12	44	1.65	3.26
Chaetodon trifascialis	5	9	0.34	2.27
Chaetodon trifasciatus	5	19	0.71	2.10
Chaetodon vagabundus	5	13	0.49	2.27
Chaetodon falcula	4	7	0.26	1.96
Chaetodon melannotus	3	9	0.34	1.39
Heniochus acuminatus	3	14	0.53	1.50
Chaetodon citrinellus	2	7	0.26	0.98
CIRRHITIDAE				
Paracirrhites forsteri	7	21	0.79	2.68
FISTULARIDAE				
Fistularia petimba	1	1	0.04	0.00
GRAMMISTIDAE				
Grammistes sexlineatus	1	1	0.04	0.00
LABRIDAE				
Halichoeres scapularis	21	141	5.29	4.21
Halichoeres centiquadrus	6	25	0.94	1.74
Thalassoma hardwicki	4	40	0.15	1.85
Coris gaimard	2	3	0.11	0.92
Labroides dimidiatus	2	2	0.08	1.00
Coris formosa	1	1	0.04	0.00
Cheilinus undulatus	1	1	0.04	0.00

Contd.....

SPECIES	FO	TA	%	H'
MURAENIDAE				
Gymnothorax undulatus	6	8	0.30	2.43
OSTRACIIDAE				
Lactoria cornuta	2	2	0.08	1.00
Ostracion meleagris	2	2	0.08	1.00
POMACANTHIDAE				
Centropyge multispinis	25	348	14.4	4.55
POMACENTRIDAE				
Dascyllus aruanus	27	657	24.64	4.46
Chromis caerulea	23	579	21.69	4.40
Dascyllus trimaculatus	17	172	6.45	3.80
Dascyllus reticulatus	14	133	4.99	3.62
Abudefduf sexfasciatus	10	89	3.34	3.16
Amphiprion chrysogaster	2	6	0.23	0.92
Pomacentrus pavo	2	4	0.15	1.00
Chrysiptera biocellata	1	3	0.11	0.00
SERRANIDAE				
Epinephelus spp.	17	59	2.21	3.82
Cephalopholis argus	4	4	0.15	2.00
SCORPAENIDAE				
Dendrochirus zebra	13	33	1.24	3.47
Pterois radiata	1	1	0.04	0.00
TETRAODONTIDAE				
Tetraodon nigropunctatus	5	23	0.86	1.19

Number of species recorded = 39.

Table 17

MASSIVE CORAL

SPECIES	FO	TA	%	H'
ACANTHURIDAE				
Acanthurus leucosternon	17	153	3.96	4.10
Acanthurus triostegus	9	88	2.28	2.96
Acanthurus spp.	8	70	1.81	2.83
Acanthurus lineatus	7	51	1.32	2.57
Naso lituratus	3	3	0.08	1.59
Naso unicornis	2	3	0.08	0.92
Naso brevirostris	1	1	0.03	0.00
Zebrasoma veliferum	1	2	0.05	0.00
APOGONIDAE				
Apogon spp.	3	53	1.37	1.39
BALISTIDAE				
Rhinecanthus aculeatus	17	51	1.32	3.84
Melichthys indicus	4	15	0.39	1.94
Rhinecanthus rectangulus	3	3	0.08	1.59
Sufflamen bursa	1	1	0.03	0.00
CAESIONIDAE				
Caesio spp.	2	200	5.18	1.00
CHAETODONTIDAE				
Chaetodon auriga	24	154	3.98	4.47
Chaetodon citrinellus	11	26	0.67	3.36
Chaetodon collare	6	40	1.04	2.12
Chaetodon trifasciatus	6	15	0.39	2.53
Chaetodon falcula	4	5	0.13	1.91
Chaetodon xanthocephalus	4	9	0.23	1.83
Heniochus acuminatus	3	17	0.44	1.55
Chaetodon lunula	2	4	0.10	1.00
Chaetodon kleinii	1	2	0.05	0.00
Chaetodon melannotus	1	2	0.05	0.00
Heniochus monoceros	1	1	0.03	0.00

Contd.....

SPECIES	FO	TA	%	H'
CIRRHITIDAE				
Paracirrhites forsteri	4	6	0.16	1.92
Cirrhites pinnulatus	1	1	0.03	0.00
DIODONTIDAE				
Diodon histrix	1	1	0.03	0.00
FISTULARIIDAE				
Fistularia petimba	1	12	0.31	0.00
GRAMMISTIDAE				
Grammistes sexlineatus	3	3	0.08	1.59
HAEMULIDAE				
Plectorhinchus orientalis	7	11	0.28	2.65
Plectorhinchus gibbosus	2	4	0.10	1.00
HOLOCENTRIDAE				
Myripristis murdjan	3	7	0.18	1.56
Sargocentron spp.	2	16	0.41	1.47
Myripristis adusta	2	2	0.05	1.00
LABRIDAE				
Halichoeres centiquadrus	22	270	6.98	4.27
Halichoeres scapularis	21	199	5.14	4.04
Labroides dimidiatus	17	105	2.72	3.94
Thalassoma hardwicki	12	70	1.81	3.36
Cheilinus trilobatus	11	70	1.81	3.32
Thalassoma lunare	11	26	0.67	3.28
Cheilinus undulatus	9	27	0.70	3.09
Novaculichthys taeniourus	8	22	0.57	2.31
Coris gaimard	6	6	0.16	2.58
Gomphosus varius	6	20	0.52	2.33
Gomphosus coeruleus	5	10	0.26	2.23

Contd.....

SPECIES	FO	TA	%	H'
Anampses caeruleopunctatus	4	6	0.16	1.92
Halichoeres marginatus	4	8	0.21	1.76
Stethojulis albovittata	4	27	0.70	1.94
Cheilinus chlorurus	3	5	0.13	1.52
Cheilinus digrammus	3	6	0.16	1.46
Bodianus axillaris	2	2	0.05	1.00
Hemigymnus melapterus	2	2	0.05	1.00
Stethojulis strigiventer	2	13	0.34	0.96
Halichoeres nebulosus	1	8	0.21	0.00
Labroides bicolor	1	1	0.03	0.00
Thalassoma herbraicum	1	2	0.05	0.00
Thalassoma purpureum	1	1	0.03	0.00
LETHRINIDAE				
Gnathodentex aureolineatus	3	300	7.76	1.59
Monotaxis grandoculis	3	4	0.10	1.50
MALACANTHIDAE				
Malacanthus latovittatus	1	2	0.06	0.00
MONOCANTHIDAE				
Alutera scripta	2	2	0.05	0.00
MUGILOLDIDAE				
Parapercis hexophthalma	5	17	0.44	2.43
MULLIDAE				
Parupeneus barberinus	10	84	2.16	3.15
Parupeneus macronema	10	56	1.45	3.10
Parupeneus bifasciatus	9	37	0.96	2.98
Mulloides flavolineatus	2	30	0.78	0.99
Parupeneus cyclostomus	2	6	0.16	0.92
Parupeneus pleurostigma	2	9	0.23	0.99
MURAENIDAE				
Echinda nebulosa	1	1	0.03	0.00
Gymnothorax undulatus	1	2	0.05	0.00

Contd....

SPECIES	FO	TA	%	H'
OSTRACIIDAE				
Lactoria cornuta	3	3	0.08	1.59
PLATACIDAE				
Platax orbicularis	2	6	0.16	0.92
POMACANTHIDAE				
Centropyge multispinis	1	18	0.47	0.00
POMACENTRIDAE				
Abudefduf sexfasciatus	15	112	2.90	3.75
Chrysiptera biocellata	6	13	0.34	2.52
Amphiprion nigripes	4	19	0.49	1.95
Chromis caerulea	3	49	1.27	1.04
Pomacentrus pavo	3	10	0.26	0.92
Plectroglyphidodon phoenixensis	2	8	0.21	1.00
Pomacentrus trilineatus	2	104	2.68	0.23
SCARIDAE				
Scarus spp.	15	881	22.80	3.34
SCORPAENIDAE				
Pterois miles	6	7	0.18	2.52
Pterois radiata	2	2	0.05	1.00
SERRANIDAE				
Epinephelus spp.	12	66	1.71	3.32
Cephalopholis argus	9	22	0.57	2.99
TETRAODONTIDAE				
Canthigaster margaritata	5	23	0.60	1.87
Tetraodon nigropunctatus	2	5	0.13	1.91
ZANCLIDAE				
Zanclus canescens	7	29	0.75	2.59

Number of species recorded = 89.

Table 18

RUBBLE

SPECIES	FO	TA	%	H'
ACANTHURIDAE				
Acanthurus triostegus	15	132	4.43	3.68
Acanthurus spp.	5	43	1.44	2.04
Acanthurus lineatus	3	10	0.34	1.48
Naso lituratus	2	6	0.20	0.92
Naso unicornis	2	4	0.13	1.00
APOGONIDAE				
Apogon fraenatus	1	6	0.20	0.00
BALISTIDAE				
Rhinecanthus aculeatus	21	116	3.90	4.18
Melichthys indicus	5	13	0.44	2.16
Rhinecanthus rectangulus	5	12	0.40	2.19
CHAETODONTIDAE				
Chaetodon citrinellus	8	30	1.01	2.54
Chaetodon auriga	1	2	0.07	0.00
FISTULARIIDAE				
Fistularia petimba	3	6	0.20	1.46
GOBIIDAE				
Gobids	9	111	3.73	3.11
HAEMULIDAE				
Plectorhinchus crientalis	3	3	0.10	0.92
LABRIDAE				
Halichoeres scapularis	24	384	12.89	4.45
Cheilinus trilobatus	6	16	0.54	2.48
Halichoeres centiquadrus	6	41	1.38	2.21
Labroides dimidiatus	5	17	0.57	2.11
Stethojulis albovittata	5	49	1.65	2.21

Contd.....

SPECIES	FO	TA	%	H'
Cheilinus undulatus	4	10	0.34	1.84
Halichoeres nebulosus	4	37	1.24	1.95
Coris gaimard	2	3	0.10	0.92
Halichoeres marginatus	2	8	0.27	0.95
Hologymnosus doliatus	2	3	0.10	0.92
Thalassoma herbraicum	2	2	0.07	1.00
Thalasomma purpureum	2	2	0.07	1.00
Stethojulis strigiventer	1	4	0.13	0.00
MULLIDAE				
Parupeneus barberinus	10	66	2.22	3.19
Parupeneus bifasciatus	8	38	1.28	2.68
Mulloides flavolineatus	5	20	0.67	2.19
Parupeneus pleurostigma	3	8	0.27	1.30
MURAENIDAE				
Gymnothorax undulatus	8	11	0.37	2.82
NEMIPTERIDAE				
Scolopsis bilineatus	7	26	0.87	2.22
PLESIOPIDAE				
Plesiops caerulolineatus	4	31	1.04	1.84
POMACENTRIDAE				
Pomacentrus trilineatus	24	202	6.78	4.38
Chrysiptera biocellata	22	305	10.24	4.09
Pomacentrus pavo	19	285	9.57	4.12
Pomacentrus sulfureus	19	117	3.93	4.09

Contd.....

SPECIES	FO	TA	%	H'
Plectroglyphidodon phoenixensis	12	109	3.66	3.49
Stegastes nigricans	3	25	0.84	1.32
Pomacentrus spp.	2	15	0.50	0.99
Abudefduf sexlineatus	1	3	0.10	0.00
Dascyllus aruanus	1	4	0.13	0.00
Stegastes lividus	1	4	0.13	0.00
SCARIDAE				
Scarus spp.	8	620	20.82	2.72
SERRANIDAE				
Epinephelus spp.	3	19	0.64	1.40

Number of species recorded = 46.

Table 19

SAND FLATS

SPECIES	FO	TA	%	H'
ACANTHURIDAE				
Acanthurus triostegus	20	172	13.22	4.06
Acanthurus leucosternon	2	6	0.46	1.00
BALISTIDAE				
Rhinecanthus aculeatus	1	2	0.15	0.00
BOTHIDAE				
Bothus pantherinus	1	1	0.08	0.00
CARANGIDAE				
Trachinotus spp.	5	16	1.23	2.25
DIODONTIDAE				
Diodon histrix	5	5	0.38	2.30
FISTULARIIDAE				
Fistularia petimba	3	5	0.38	0.99
GOBIIDAE				
Gobids	1	6	0.46	0.00
KUHLIDAE				
Kuhlia mugil	3	39	3.00	1.58
LABRIDAE				
Halichoeres scapularis	26	356	27.36	4.43
Stethojulis albovittata	8	28	2.15	2.57
Cheilio inermis	6	13	1.00	1.78
Thalassoma hardwicki	2	5	0.38	0.72
LETHRINIDAE				
Gnathodentex aureolineatus	2	3	0.23	1.00

Contd.....

SPECIES	FO	TA	%	H'
MUGILIDAE				
Crenemugil crenilabis	5	26	2.00	1.76
MUGILOIDIDAE				
Parapercis hexophthalma	14	51	3.92	3.59
MULLIDAE				
Parupeneus barberinus	18	132	10.15	3.92
Parupeneus macronema	10	54	4.15	3.05
Parupeneus bifasciatus	7	23	1.77	2.26
Mulloides flavolineatus	6	41	3.15	2.48
Parupeneus pleurostigma	1	2	0.15	0.00
OSTRACIIDAE				
Lactoria cornuta	1	1	0.08	0.00
POLYNEMIDAE				
Polynemus spp.	9	25	1.92	2.86
SCARIDAE				
Scarus spp.	5	206	15.84	1.20
SCORPAENIDAE				
Dendrochirus spp.	5	12	0.92	1.78
Pterois miles	4	4	0.31	1.00
SPHYRAENIDAE				
Sphyraena spp.	7	31	2.38	2.38
THERAPONIDAE				
Therapon jarbua	8	36	2.77	2.80

Number of species recorded = 28.

Table 20

SEA GRASS BEDS

SPECIES	FO	TA	%	H'
ACANTHURIDAE				
Acanthurus spp.	15	111	2.69	3.35
Acanthurus triostegus	14	173	4.20	3.65
Zebrasoma veliferum	9	21	0.51	2.89
Acanthurus leucosternon	6	14	0.34	2.26
Naso unicornis	6	22	0.53	2.38
Naso brevirostris	2	5	0.12	0.97
APOGONIDAE				
Apogon fraenatus	1	8	0.19	0.00
Apogon taeniophorus	1	6	0.15	0.00
BALISTIDAE				
Balistoides viridescens	4	8	0.19	1.91
Pseudobalistes flavimarginatus	3	12	0.29	1.19
Rhinecanthus aculeatus	1	1	0.02	0.00
BELONIDAE				
Tylosurus spp.	4	38	0.92	1.77
BLENNIDAE				
Omobranchus spp.	4	42	1.02	1.98
BOTHIDAE				
Bothus pantherinus	6	11	0.27	2.56
CHAETODONTIDAE				
Chaetodon auriga	18	101	2.45	3.94
Chaetodon melannotus	9	37	0.90	3.00
Chaetodon xanthocephalus	7	33	0.80	2.12
Heniochus acuminatus	7	25	0.61	2.70
Chaetodon citrinellus	1	2	0.05	0.00
Chaetodon collare	1	2	0.05	0.00
Chaetodon kleinii	1	2	0.05	0.00
Chaetodon trifasciatus	1	5	0.12	0.00

Contd.....

SPECIES	FO	TA	%	H'
DIODONTIDAE				
Diodon histrix	9	17	0.41	2.90
FISTULARIIDAE				
Fistularia petimba	11	149	3.61	2.73
KUHLIDAE				
Kuhlia mugil	3	143	3.48	1.18
LABRIDAE				
Halichoeres scapularis	20	332	8.05	3.75
Stethojulis albovittata	17	167	4.05	3.85
Stethojulis strigiventer	16	183	4.44	3.49
Cheilio inermis	15	84	2.04	3.52
Crois gaimard	8	18	0.44	2.73
Hologymnosus doliatus	7	13	0.32	2.66
Anampses caeruleopunctatus	3	9	0.22	1.39
Cheilinus trilobatus	2	3	0.07	0.92
Halichoeres centiquadrus	2	6	0.15	0.65
Cheilinus undulatus	1	4	0.10	0.00
Gomphosus coeruleus	1	1	0.02	0.00
Halichoeres marginatus	1	1	0.02	0.00
Thalassoma amblycephalum	1	2	0.05	0.00
Thalassoma hardwicki	1	1	0.02	0.00
LETHRINIDAE				
Monotaxis grandoculis	2	4	0.10	0.81
MALACANTHIDAE				
Malacanthus latovittatus	1	1	0.02	0.00
MONOCANTHIDAE				
Alutera scripta	11	28	0.68	3.35
Cantherinus paradalis	4	5	0.12	1.91
MUGILIDAE				
Crenemugil crenilabis	2	6	0.15	0.92

Contd....

SPECIES	FO	TA	%	H'
MUGILOIDIDAE				
Parapercis hexophthalma	2	5	0.12	0.97
MULLIDAE				
Parupeneus macronema	13	81	1.97	3.50
Mulloides flavolineatus	12	115	2.79	3.45
Parupeneus barberinus	11	69	1.67	3.25
Parupeneus bifasciatus	9	52	1.26	2.83
Parupeneus pleurostigma	7	36	0.87	2.53
Parupeneus cyclostomus	1	2	0.05	0.00
NEMIPTERIDAE				
Scolopsis bilineatus	1	2	0.05	0.00
OSTRACIIDAE				
Lactoria cornuta	2	2	0.05	1.00
Ostracion meleagris	1	2	0.05	0.00
POLYNEMIDAE				
Polynemus spp.	3	19	0.46	1.08
POMACENTRIDAE				
Abudefduf sexfasciatus	8	40	0.97	2.79
SCARIDAE				
Scarus spp.	18	1752	42.50	4.21
SCORPAENIDAE				
Pterois miles	7	15	0.36	2.79
Dendrochirus zebra	2	3	0.07	0.92
SIGANIDAE				
Signanus stellatus	1	2	0.05	0.00

Contd....

SPECIES	FO	TA	%	H'
SPHYRAENIDAE				
Sphyraena spp.	3	38	0.92	1.15
TETRAODONTIDAE				
Tetraodon nigropunctatus	5	6	0.15	2.25
Canthigaster margaritatus	1	2	0.05	0.00
THERAPONIDAE				
Therapon jarbua	1	4	0.10	0.00
ZANCLIDAE				
Zanclus canescens	6	19	0.46	2.33

Number of species recorded = 65

Table 21

REEF SLOPE

SPECIES	FO	TA	%	H'
ACANTHURIDAE				
Acanthurus spp.	19	411	6.50	4.00
Acanthurus leucosternon	17	299	4.73	3.55
Acanthurus lineatus	14	210	3.32	3.48
Naso unicornis	13	163	2.58	3.35
Zebrasoma veliferum	8	21	0.33	2.41
Naso lituratus	7	21	0.33	2.45
Acanthurus triostegus	6	28	0.44	1.99
Naso vlamingii	3	34	0.54	1.38
Naso brevirostris	2	19	0.30	0.63
APOGONIDAE				
Apogon spp.	3	76	1.20	1.26
BALISTIDAE				
Melichthys indicus	13	168	2.66	4.52
Odonus niger	11	131	2.07	3.34
Rhinecanthus aculeatus	11	72	1.14	3.27
Balistapus undulatus	7	22	0.35	2.69
Rhinecanthus rectangulus	5	10	0.16	2.11
Sufflamen bursa	5	12	0.19	2.25
Balistoides viridescens	4	33	0.52	1.43
Balistoides conspiculum	4	4	0.06	2.00
Sufflamen fraenatus	4	9	0.14	1.75
Balistes ringens	3	6	0.09	1.59
Pseudobalistes flavi marginatus	1	1	0.02	0.00
CAESIONIDAE				
Caesio spp.	5	159	2.52	2.10
CARANGIDAE				
Elagatis pinnulatus	5	6	0.09	2.25

Contd.....

SPECIES	FO	TA	%	H'
CHAETODONTIDAE				
Chaetodon auriga	17	103	1.63	3.78
Chaetodon collare	13	148	2.34	3.52
Forcipiger spp.	10	17	0.27	3.02
Chaetodon trifasciatus	8	25	0.40	2.84
Chaetodon meyeri	7	12	0.19	2.75
Hemitaurichthys zoster	7	134	2.12	2.64
Chaetodon trifascialis	6	14	0.22	2.47
Chaetodon xanthocephalus	6	24	0.38	2.24
Chaetodon falcula	5	9	0.14	2.19
Heniochus acuminatus	5	46	0.73	2.18
Chaetodon citrinellus	4	17	0.27	1.87
Chaetodon bennetti	3	10	0.16	0.72
Chaetodon vagabundus	3	5	0.08	1.52
Chaetodon plebeius	2	4	0.06	1.00
Chaetodon lunula	2	2	0.03	1.00
Chaetodon triangulum	2	4	0.06	0.00
Heniochus monoceros	2	6	0.09	0.92
Chaetodon melannotus	1	4	0.06	0.00
CIRRHITIDAE				
Paracirrhites forsteri	10	53	0.84	2.91
Cirrhites pinnulatus	2	4	0.06	1.00
DIODONTIDAE				
Diodon histrix	2	3	0.05	0.92
GRAMMISTIDAE				
Grammistes sexlinatus	6	9	0.14	2.27
HAEMULIDAE				
Plectorhinchus orientalis	9	14	0.22	3.03
Plectorhinchus gibbosus	5	83	1.31	2.24

Contd.....

SPECIES	FO	TA	%	H'
HOLOCENTRIDAE				
Sargocentron spp.	4	14	0.22	1.84
Myripristis murdjan	3	11	0.17	1.32
Myripristis adusta	2	5	0.08	0.97
LABRIDAE				
Halichoeres scapularis	17	299	4.73	3.55
Thalassoma hardwicki	14	142	2.25	3.68
Thalassoma lunare	14	88	1.39	3.24
Halichoeres centiquadrus	11	162	2.56	3.32
Cheilinus undulatus	10	50	0.79	3.07
Gomphosus varius	7	24	0.38	2.60
Gomphosus coeruleus	6	14	0.22	2.35
Labroides dimidiatus	6	46	0.73	2.43
Thalassoma herbraicum	6	14	0.22	2.11
Cheilinus trilobatus	5	35	0.55	2.16
Coris gaimard	4	7	0.11	0.98
Halichoeres nebulosus	4	19	0.30	1.89
Halichoeres marginatus	4	17	0.27	1.78
Novaculichthys taeniourus	4	14	0.22	1.93
Bodianus axillaris	2	5	0.08	0.72
Hemigymnus fasciatus	2	3	0.05	0.92
Hologymnosus doliatus	2	3	0.05	0.92
Labroides bicolor	2	3	0.05	0.92
Stethojulis albovittata	2	7	0.11	0.98
Anampses caeruleopunctatus	1	1	0.02	0.00
Cheilinus chlorurus	1	2	0.03	0.00
Coris formosa	1	4	0.06	1.20
Thalassoma amblycephalum	1	3	0.05	0.00
Thalassoma purpureum	1	2	0.03	1.00
LETHRINIDAE				
Monotaxis grandoculis	3	5	0.08	1.52
Gnathodentex aureolineatus	1	6	0.09	0.00

Contd.....

SPECIES	FO	TA	%	H'
LOBOTIDAE				
Lobotes surinamensis	1	1	0.02	0.00
LUTJANIDAE				
Aprion viriscens	2	3	0.05	0.92
MALACANTHIDAE				
Malacanthus latovittatus	2	2	0.03	1.00
MONOCANTHIDAE				
Cantherinus paradalis	3	7	0.11	1.72
Alutera scripta	1	1	0.02	0.00
MUGILOIDIDAE				
Parapercis hexophthalma	6	35	0.55	2.38
MULLIDAE				
Parupeneus barberinus	12	101	1.60	3.33
Parupeneus bifasciatus	11	80	1.27	3.31
Mulloides flavolineatus	4	33	0.52	1.95
Parupeneus macronema	4	20	0.32	1.61
Parupeneus pleurostigma	3	27	0.43	2.35
Parupeneus cyclostomus	2	6	0.09	0.92
MURAENIDAE				
Echinda zebra	2	2	0.03	1.00
Gymnothorax undulatus	1	1	0.02	0.00
Gymnothorax spp.	1	1	0.02	0.00
NEMIPTERIDAE				
Scolopsis bilineatus	2	8	0.13	1.00
OSTRACIIDAE				
Ostrac ion meleagris	4	6	0.09	1.79
Lactoria cornuta	3	8	0.13	1.50

Contd.....

SPECIES	FO	TA	%	H'
PLATACIDAE				
Platax orbicularis	4	12	0.19	1.92
POMACANTHIDAE				
Pomacanthus imperator	4	7	0.11	2.24
Centropyge multispinis	2	8	0.13	0.81
Pomacanthus semicirculatus	1	4	0.06	0.00
Pygoplites diacanthus	1	1	0.02	0.00
POMACENTRIDAE				
Chrysiptera biocellata	11	251	3.97	3.20
Abudefduf sexfasciatus	9	80	1.27	3.03
Chromis caerulea	8	405	6.41	2.87
Dascyllus aruanus	7	189	2.99	2.53
Dascyllus trimaculatus	5	33	0.52	2.06
Pomacentrus spp.	5	92	1.46	2.32
Dascyllus reticulatus	4	112	1.77	1.81
Amphiprion nigripes	2	10	0.16	0.72
Chromis dimidiata	1	4	0.06	0.00
Plectroglyphidodon phoenixensis	1	8	0.13	0.00
SCARIDAE				
Scarus spp.	15	525	8.31	3.30
SCORPAENIDAE				
Pterois miles	5	11	0.17	2.23
SERRANIDAE				
Epinephelus spp.	14	84	1.33	3.27
Cephalopholis argus	6	27	0.43	1.90
Anthias squamipinnes	3	250	3.96	1.52
Cephalopholis spp.	3	5	0.08	1.52
Variola louti	1	1	0.02	0.00

Contd.....

SPECIES	FO	TA	%	H'
TETRAODONTIDAE				
Canthigaster margaritata	6	23	0.36	2.36
Tetraodon nigropunctatus	5	8	0.13	2.02
Canthigaster valentini	3	6	0.09	1.59
ZANCLIDAE				
Zanclus canescens	10	50	0.79	2.90

Number of species recorded = 121

Scarus spp. contributed to the highest density (525 nos) of fishes recorded from the region contributing to 8.31% and a diversity of 3.30. Pterois miles occurred only 5 times. Of the five species of serranids recorded, Epinephelus spp. was frequent (14 times) while others occurred 3 to 6 times excepting Variota louti that was found only once. In terms of numerical density Anthias squamipinnes (250 nos) was abundant, followed by Epinephelus spp. (84 nos).

Generally tetraodontidae species were rare with only three species being recorded. Canthigaster margaritata accounted for 23 nos. A total of 50 individuals of Zanclus canescens were recorded on 10 samples.

2. Seasonal variation in community parameters

a. Live coral: Variation in total number of individuals during the pre-monsoon, was high (61 to 150) in 1991 while the same in 1992 was relatively low (57 to 86). January 1, March 4 and February 2 (1991) recorded 150, 115 and 108 individuals respectively (Table 22 A). In the monsoon, June 3, '91 recorded the least count (63) while in June 2, 1992 it was 240 counts (Table 22 B & E). In general, May in both the years accounted for more fishes (106 to 126 nos). Counts during post-monsoon were also not consistent (72 to 141). Maximum count (141 nos) was recorded in October 3 (Table 22 C).

Total number of species recorded, ranged between 7 and 16 in pre-monsoon, with the maximum (16) during February 2 and April 6, 1991 (Table 22 A). Three samples during April 7 ('91), 5 and 6 ('92) accounted for least species counts of 8, 7 and 7 respectively. Species counts were stable (10 to 15) during monsoon, while in post-monsoon a minimum of 8 species in December 7 and a maximum of 14 species in September 1 were recorded (Table 22 B, E & C).

During pre-monsoon, species diversity was high only in February 2 (3.39) and April 6 (3.35) while in all other samples it was below 3.00 (Table 22 A). May 2, June 3, July 4 in '91 recorded diversities of 3.16, 3.13 and 3.28 respectively, while the least (1.77) was in June 2, '92 (Table 22 B & E). Diversity during other monsoon months ranged between 2.81 and 2.90. In the post-monsoon, all samples taken in September 1, 2 and a single sample in November 6 had diversities of 3.02, 3.04 and 3.26, while October 3, 4 and December 7 registered values between 2.44 and 2.86 (Table 22 C).

Evenness in distribution of species was maximum (0.04) in April 7, '91 and minimum (0.65 and 0.67) in two samples taken in April 5, 6 '92 during pre-monsoon. In general a majority of samples registered values between 0.80 and 0.88 (Table 22 A & D). During monsoon of '91, May 1, 2, June 3 and July 4 showed relatively stable patterns of distribution (0.81 to 0.87) while in

August 5 it was 0.78. Two monsoon samples taken in '92 however showed uneven distribution (0.79 and 0.51). Distribution was not consistent during post-monsoon with a minimum (0.71) in October 4 and a maximum (0.93 and 0.91) in December 7 and November 6 respectively (Table 22 C). Except in September 1 (0.79) other samples indicated a relatively stable distribution (0.82 to 0.86).

b. Massive coral: Total counts of fishes pictured different trends during the pre-monsoon season in both years. A minimum of 87 and a maximum of 155 individuals were recorded in '91 in March 5 and February 2 (Table 23 A) while the same in '92 varied between 57 and 447 in February 2 and April 6 (Table 23 D). Monsoon counts also fluctuated between 54 and 152. Counts were high in two samples, one in June 3, '91 (118 nos) and the other in May 1, '92 (152 nos), while other samples showed a count range of 54 to 89 (Table 23 B & E). A similar trend was seen during post-monsoon where the minimum (43 nos) were recorded in October 3 and a maximum of 396 nos in November 5 (Table 23 C).

A greater number of species were found during the pre-monsoon ('91) with counts of 22, 23 and 25 in February 2, 3 and March 4 (Table 23 A). Total number of species in other samples varied between 12 and 20. During monsoon ('91) 17 to 21 species were encountered with a maximum (21) in May 1, while two samples, each taken during May 1 and June 2, '92 recorded 14 and 11 species (Table 23 B & E). Species counts during post-monsoon ranged between 14 and 23 (Table 23 C).

Samples taken in February and March in both the years during pre-monsoon (Table 23 A & D) registered relatively high diversities of 4.08 to 4.17 and 3.39 to 3.51 respectively. Other samples in 1991 recorded diversities between 3.38 and 3.84, while in 92 it was between 2.43 and 2.74. Species diversity, generally was not stable during pre-monsoon. During monsoon '91, species diversity was relatively stable (3.54 to 3.98) while it was low (2.14 and 2.97) in May 1 and June 2 of '92 (Table 23 B & E). Diversity was above 3.00 in the post-monsoon with a maximum of 3.79 and a minimum of 3.00 in September 2 and November 5 respectively (Table 23 C).

Evenness in distribution of species was generally stable (0.86 to 0.90) during pre-monsoon of '91 while it varied greatly (0.61 to 0.95) in the same season in '92. A similar trend was observed in monsoon samples (0.86 to 0.93) except during May 1, '92, where it was observed to be most uneven (0.56). A relatively uneven distribution (0.67, 0.71 and 0.73) was recorded in October 4 and November 5, 6 (Table 22 C) while it was stable in other samples (0.85 to 0.91).

c. Rubble: Variation in the total counts of fishes from the sub-habitat was lower (79 to 157) during pre-monsoon of '91 as compared to that in '92, where it was between 39 and 167. In the same year (Table 24 D), low counts were registered in February 2 (77) and April 6 (66). 132 individuals were recorded in May 1

and August 5 of '91 while least counts were observed in June 2 (87) of '92. In the same year May 1, recorded 177 counts. A fluctuating pattern (53 to 161) was evident during post-monsoon (Table 24 C).

Total number of species generally varied between 9 and 12. Highest counts (16 and 17) occurred during the pre-monsoon ('91) in January 1 and March 4 (Table 24 A). During monsoon 9 to 12 species were regularly observed except in May 1 (14 nos) and August 5 (13 nos) where it was relatively high (Table 24 B & E). Total number of species occurring in post-monsoon was stable (9 to 12 nos) in post-monsoon except in November 6, where 13 species were recorded (Table 24 C).

Species diversity in pre-monsoon ('91) was generally above 3.00 in all samples (Table 24 A) with January 1 (3.66) and March 4 (3.69) accounting for high diversity, while it was low (2.80) in March 5 ('91). In the pre-monsoon of '92 diversity values were generally low (below 2.20) except in February 2 and April 6 where 3.15 and 3.08 were recorded respectively (Table 24 D). Monsoon also showed a relatively high diversity (3.06 to 3.50) except in July 4, 1991 and May 1 '92 which recorded 2.85 and 2.28 respectively (Table 24 B & E). Variation in species diversity was high (1.77 to 3.37) in the post-monsoon. Four samples accounted for diversities above 3.00 while 1.77, 2.80 and 1.95 were recorded in October 3, March 5 and December 7 (Table 24 C).

During the pre-monsoon of '91, species distribution was relatively even and stable (0.85 to 0.93) in all 7 samples, while in '92 it was unstable (0.61 to 0.93) among 6 samples (Table 24 A & D). All samples taken during monsoon had even distribution except in May 1, '92 (Table 24 E) when it was 0.66. Highest variation (0.53 to 0.91) in species distribution was observed in post-monsoon (Table 24 C). Samples in October 3 (0.53) and December 7 (0.62) accounted for low evenness, while the trend in other samples generally remained stable.

d. Sand flats: Total fish counts during all seasons were generally below 100. In pre-monsoon of '91, the least count (28) was recorded in March 4, while a maximum of 87 was found in February 2 (Table 25 A). 27 individuals were the least recorded in pre-monsoon of '92 while the highest was 129 nos encountered in April 6 (Table 25 D). During the monsoon of '91, counts ranged between 21 (May 1) and 75 (July 4). A relatively high count (135 nos) was obtained in monsoon of '92 in June 2, while in May 1, it was 51 (Table 25 E). A maximum of 43 individuals and a minimum of 14 were recorded in September 1 and December 7 respectively, during post-monsoon (Table 25 C). Counts in other samples ranged from 33 to 41.

Number of species recorded in samples during pre-monsoon generally varied between 6 to 8, except in February 2 and March 5 of '91 (Table 25 A) when they numbered 11 and 10 respectively.

Monsoon also showed a similar trend (Table 25 B & E) recording 6 to 8 species. A maximum of 8 or 9 species were recorded in June 3, July 4 ('91) and June 2 ('92). Species counts were generally low (4 to 8) during post-monsoon with a majority of samples recording either 4 or 5 species (Table 25 C).

Species diversity fluctuated greatly during the pre-monsoon of '91 (Table 25 A) with a minimum of 0.96 and a maximum of 3.02, both in May 4, 5. Other samples had diversities of above 2.00 except in January 1 (1.92) and February 3 (1.79). Pre-monsoon of '92 had a stable diversity with most of the samples between 2.33 and 2.73 except in April 6 when it was 1.27 (Table 25 D). Species diversity in monsoon ('91) ranged between 2.02 (May 2) and 2.95 (July 4). The two samples taken in '92 differed markedly (2.37 and 1.40) during monsoon (Table 25 E). Diversity varied significantly during post-monsoon (1.61 and 2.72). Relatively high values (2.17, 2.06 and 2.72) were observed in September 2 and November 5, 6 respectively (Table 25 C).

Similar to the fluctuating trend in diversity during pre-monsoon of '91, distribution also varied between 0.37 and 0.91 (Table 25 A). Three samples, each in February 2 (0.80), March 5 (0.91) and April 6 (0.82) were relatively stable, while an overall stability (0.83 to 0.97) was observed in most samples in '92 except in April 6 (0.45) when least evenness occurred (Table 25 D). Distribution in monsoon (1991) varied between 0.71 and 0.98

while fluctuation was higher (0.84 and 0.47) between samples taken in May and June '92 (Table 25 E). Most even distribution (0.91) of species occurred in November 6, while the general trend was between 0.80 and 0.85. Relatively uneven distribution (0.77) was observed during September 2 and October 4 (Table 25 C).

e. Seagrass beds: Total counts during pre-monsoon of '91 varied between 72 (April 7) and 310 (March 4). Other samples recorded counts between 185 and 228 (Table 26 A). In '92, the fluctuation during pre-monsoon was to a lesser magnitude (139 to 204 nos) with most of the counts ranging between 139 and 171 nos (Table 26 D). Variation in monsoon was also significant with a minimum (90 nos) in June 3 and a maximum in May 1 (203 nos). Two samples taken in May 1 and June 2 of '92 recorded 56 and 59 individuals respectively. A fluctuating trend was also seen during post-monsoon. Two samples in October 3, 4 (52, 64 nos) and one in December 7 (63 nos) recorded low counts while the highest (350 nos) was found in September 2 (Table 26 C).

Total number of species observed during both the years in pre-monsoon were between 13 and 17. Mach 4 ('91) recorded a highest of 20 species while a minimum of 10 and 12 species were found in February 2 and March 3 in '92 (Table 26 A & D). Species numbers were relatively stable in the monsoon recording 14 to 17 species (Table 26 B & E), while the variation was relatively high in post-monsoon with a range of 8 to 17 species (Table 26 C).

High species diversity (3.44, 3.00 and 3.38) was found in March 4, 5 and April 7 respectively (Table 26 A) in pre-monsoon of '91, while other samples showed diversities above 2.00. During the same season in '92, a minimum (1.89) was observed in March 4 (Table 26 D) while other samples had diversities above 2.00. Species diversity in monsoon in both years was generally high 3.10 to 3.41) except in one sample taken in May 1 ('91) where it was 2.81 (Table 26 B & E). A relatively high variation (1.71 to 3.47) was seen during post-monsoon. Low values (1.93 and 1.71) were registered in September 1 and November 5 (Table 26 C).

Evenness in species distribution varied greatly in pre-monsoon (0.61 to 0.91) in '91 while it was generally uneven (0.50 to 0.67) in 1992 (Table 26 A & D). Distribution was most even (0.91) in April 7. In general the variation was high in monsoon (0.69 to 0.90) and post-monsoon (0.51 to 0.91). In '91 an even distribution (0.90) was observed in May 2. Two samples, each taken in May and June ('92) had a stable distribution (0.89 and 0.85 respectively). During post-monsoon, October 4 (0.91) accounted for an even distribution (Table 26 C).

f. Reef slope: Highest total counts of fishes (414 nos) were recorded in April 7 ('91) during pre-monsoon (Table 27 A). This was followed by 388, 371 and 341 individuals observed in January 1 and February 2, 3. Other samples recorded between 228 and 253 individuals (Table 27 A). In March 3 ('92) a minimum of 169

individuals were recorded while February 2 (386 nos) recorded a relatively high count (Table 27 D). During monsoon ('91) May 1, 2 accounted for 340 and 304 counts respectively while August 3 recorded 251 counts. A low count was observed in May 1, '92 (Table 27 E). Total counts varied between 199 (October 3) and 387 (September 1) during post-monsoon. November 5 recorded 307 individuals while other samples recorded counts between 219 and 270 (Table 27 C).

Number of species recorded in pre-monsoon ('91) was generally stable between 35 to 45 species except in March 4 where it was 30. Variation was high (14 to 32 species) in '92. During monsoon 39 species were recorded in May 2, while two other samples taken in the same season accounted for 31 and 32 respectively (Table 27 B). Least count (25 nos) was in May 1, '92 (Table 27 E). Species number recorded in post-monsoon was generally low (21 to 27 nos) except in October 4 where it was 31 species (Table 27 C).

Species diversity was generally between 4.28 and 4.61 in pre-monsoon ('91) except in April 7 which recorded 3.96 (Table 27 A). A majority of samples in the pre-monsoon of '92 had a species diversity between 3.72 and 3.77, with a maximum of 4.11 in February 2 and a minimum of 2.86 in January 1. Diversity in all samples taken during monsoon were higher than 4.27 except in May

Tables 22 to 27. Total number of individuals (I), number of species (S), diversity index (H') and evenness inded (J') for each of the census conducted during pre-monsoon, monsoon and post-monsoon seasons on the five sub-habitats and the reef slope. (January 1991 to June 1992)

Table 22

LIVE CORAL

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	150	108	81	115	61	99	86
	S	12	16	11	11	10	16	8
	H'	2.57	3.39	2.80	2.73	2.90	3.35	2.81
	J'	0.72	0.85	0.81	0.79	0.87	0.84	0.94
B	MONSOON							
		MY	MY	J	JY	AG		
	I	109	106	63	65	85		
	S	10	15	12	14	13		
	H'	2.81	3.16	3.13	3.28	2.90		
	J'	0.85	0.81	0.87	0.86	0.78		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	72	123	141	78	85	129	91
	S	14	12	10	9	11	12	8
	H'	3.02	3.04	2.86	2.44	2.84	3.26	2.79
	J'	0.79	0.85	0.86	0.71	0.82	0.91	0.93
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	84	57	82	86	83	61	
	S	10	9	11	11	7	7	
	H'	2.70	2.52	2.87	2.65	2.42	2.48	
	J'	0.81	0.79	0.83	0.77	0.65	0.67	

E MONSOON (2 samples) May, June | I = 126, 240; H' = 2.83, 1.77; J' = 0.79, 0.51; S = 12, 11.

Table 23

MASSIVE CORAL

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	118	155	130	126	87	106	88
	S	18	22	23	25	15	16	19
	H'	3.60	3.84	4.08	4.17	3.38	3.47	3.76
	J'	0.86	0.86	0.90	0.90	0.87	0.87	0.89
B	MONSOON							
		MY	MY	J	JY	AG		
	I	81	57	118	89	54		
	S	21	15	20	17	17		
	H'	3.83	3.54	3.98	3.58	3.80		
	J'	0.87	0.91	0.92	0.88	0.93		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	82	116	43	212	396	198	72
	S	15	18	14	23	19	22	14
	H'	3.42	3.79	3.48	3.03	3.00	3.24	3.22
	J'	0.88	0.91	0.91	0.67	0.71	0.73	0.85
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	289	57	117	201	206	447	
	S	20	12	17	15	17	16	
	H'	2.66	3.39	3.51	2.74	2.65	2.43	
	J'	0.62	0.95	0.86	0.70	0.65	0.61	
E	MONSOON (2 samples) May, June	I = 152, 66; H' = 2.14, 2.97; J' = 0.56, 0.86; S = 14, 11.						

Table 24

RUBBLE

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	157	89	99	145	79	103	97
	S	16	12	12	17	9	11	12
	H'	3.66	3.05	3.20	3.69	2.80	3.21	3.11
	J'	0.92	0.85	0.89	0.90	0.88	0.93	0.87
B	MONSOON							
		MY	MY	J	JY	AG		
	I	132	93	122	100	132		
	S	14	12	11	9	13		
	H'	3.56	3.25	3.06	2.85	3.45		
	J'	0.94	0.99	0.88	0.90	0.93		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	121	80	141	53	57	78	161
	S	12	12	10	10	9	13	9
	H'	3.14	3.18	1.77	3.03	2.80	3.37	1.95
	J'	0.88	0.89	0.53	0.91	0.88	0.91	0.62
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	160	77	167	39	166	66	
	S	10	13	11	6	11	10	
	H'	2.13	3.15	2.12	2.17	2.18	3.08	
	J'	0.64	0.85	0.61	0.84	0.63	0.93	
E	MONSOON (2 samples) May, June	I = 177, 87; H' = 2.28, 3.22; J' = 0.66, 0.93; S = 11,11.						

Table 25

SAND FLATS

Sample No.	1	2	3	4	5	6	7
A PRE-MONSOON 1991							
	J	F	F	M	M	A	A
I	67	87	35	28	36	32	47
S	7	11	5	6	10	7	8
H'	1.92	2.76	1.79	0.96	3.02	2.30	2.14
J'	0.68	0.80	0.77	0.37	0.91	0.82	0.71
B MONSOON							
	MY	MY	J	JY	AG		
I	21	45	45	75	29		
S	6	6	8	9	6		
H'	2.53	2.02	2.12	2.95	2.14		
J'	0.98	0.78	0.71	0.93	0.83		
C POST-MONSOON							
	S	S	O	O	N	N	D
I	43	39	33	26	36	41	14
S	5	7	4	5	6	8	4
H'	1.85	2.17	1.61	1.79	2.06	2.72	1.69
J'	0.80	0.77	0.81	0.77	0.80	0.91	0.85
D PRE-MONSOON 1992							
	J	F	M	M	A	A	
I	50	48	27	38	44	129	
S	8	7	7	6	7	7	
H'	2.67	2.33	2.40	2.40	2.73	1.27	
J'	0.89	0.83	0.85	0.93	0.97	0.45	

E MONSOON (2 samples) May, June | I = 51, 135; H' = 2.37, 1.40; J' = 0.84,0.47; S = 7, 8.

Table 26

SEA GRASS BEDS

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	201	185	190	310	228	205	72
	S	16	13	14	20	17	16	13
	H'	2.45	2.51	2.64	3.44	3.00	2.73	3.38
	J'	0.61	0.68	0.69	0.80	0.86	0.68	0.91
B	MONSOON							
		MY	MY	J	JY	AG		
	I	203	114	90	102	129		
	S	17	14	14	15	15		
	H'	2.81	3.41	3.33	3.41	3.10		
	J'	0.69	0.90	0.87	0.87	0.79		
C	POST-MONSOON							
		S	S	O	O	N	N	D
	I	148	350	52	64	146	173	63
	S	13	13	8	14	10	17	11
	H'	1.93	2.39	2.65	3.47	1.71	2.51	2.99
	J'	0.52	0.65	0.88	0.91	0.51	0.61	0.86
D	PRE-MONSOON 1992							
		J	F	M	M	A	A	
	I	204	154	163	139	171	151	
	S	13	10	12	14	16	13	
	H'	2.24	2.22	2.08	1.89	2.37	2.04	
	J'	0.61	0.67	0.58	0.50	0.59	0.55	
E	MONSOON (2 samples) May, June	I = 56, 59; H' = 3.38, 3.22; J' = 0.89, 0.85; S = 14, 14.						

Table 27

REEF SLOPE

	Sample No.	1	2	3	4	5	6	7
A	PRE-MONSOON 1991							
		J	F	F	M	M	A	A
	I	388	371	341	228	237	253	414
	S	39	36	39	30	45	34	36
	H'	4.40	4.28	4.54	4.37	4.61	4.59	3.96
	J	0.83	0.83	0.86	0.89	0.84	0.93	0.77
B	MONSOON							
		MY	MY	AG				
	I	340	304	251				
	S	31	39	32				
	H'	3.94	4.58	4.35				
	J'	0.80	0.87	0.87				
C	POST-MONSOON							
		S	S	O	O	N	D	
	I	387	270	199	260	307	219	
	S	29	27	24	31	21	24	
	H'	3.80	3.76	3.94	4.06	3.09	3.64	
	J'	0.78	0.79	0.86	0.82	0.70	0.79	
D	PRE-MONSOON 1992							
		J	F	M	A	A		
	I	256	386	169	290	300		
	S	14	32	18	31	23		
	H'	2.86	4.11	3.72	3.75	3.77		
	J'	0.75	0.82	0.74	0.76	0.83		
E	MONSOON (1 sample) May	I = 151; H' = 4.27; J' = 0.92; S = 25.						

1 ('91) where it was 3.94 (Table 27 B). The trend in post-monsoon was relatively low (3.09 to 3.94), but for a high value of 4.06 recorded in October 4 (Table 27 C).

Evenness of distribution of species during pre-monsoon of '91 was most even (0.93) in April 6 while it remained stable (0.83 to 0.89) in most of the samples (Table 27 A). An uneven distribution (0.77) was observed in April 7. A relatively uneven distribution (Table 27 D) was found in pre-monsoon of '92 (0.74 to 0.76) except in February 2 and April 5 where it was 0.82 and 0.83 respectively. During the monsoon ('91) a stable distribution (0.80 to 0.87) was observed, while a single sample taken in May ('92) was found to be even accounting for a value of 0.92 (Table 27 E). Two samples in October 3, 4 had relatively higher evenness (0.86 and 0.82 respectively) while others were relatively uneven but stable (0.70 to 0.79).

3. Distribution of Species

Species recorded in each family on the five sub-habitats during the entire study period are listed in the order of pooled frequency of occurrence in Table 28 together with pooled total abundances, frequency of occurrence and percentage abundance on individual habitats with habitat diversity and evenness of distribution.

Acanthurus triostegus (Photo 24) was recorded 58 times and indicated a high density of 565 nos. The species showed equal preference

towards sand (30.44%) and seagrass (30.62%) followed by rubble and massive coral forming proportions of 23.36 and 15.58% respectively (Fig. 23 C). It had a habitat diversity of 1.95 and was relatively even in distribution (0.98). Acanthurus spp. (224 nos) and Acanthurus leucosternon (Photo 25) (174 nos) occurred in relatively high numbers (Fig 23 A & E) the former dominating seagrass beds (49.55%) while the latter preferred massive coral (87.93%). Distribution in A. leucosternon was uneven (0.34) with a low habitat diversity (0.67) while Acanthurus spp. were evenly distributed (0.93) with a diversity of 1.48. Other species in the family were less abundant registering low distribution and habitat diversity, except Naso unicornis where habitat diversity was 1.03. Acanthurus lineatus and Naso lituratus (Photo 26, 27) dominated rubble zones (83.61% and 66.67% respectively). N. unicornis, N. brevirostris and Zebrasoma veliferum were observed mainly on seagrass beds with proportions of 75.86%, 83.33% and 91.30% respectively.

Three species of apogonids were observed with low habitat diversities. Apogon fraenatus (14 nos) indicated nearly equal preference towards rubble (42.86%) and seagrass (57.14%) while Apogon spp. and Apogon taeniophorus preferred only massive coral and seagrass beds.

The most abundant balistid was Rhinecanthus aculeatus (Photo 28) (175 nos) that occurred 31 times (Fig 24 A). Though uneven in distribution (0.52) it had a relatively high habitat diversity of 1.21 showing preference towards rubble (66.29%). Other species recorded low counts between 12 to 43. A single occurrence of Balistes bursa (Photo 29) on massive coral zone was recorded. Melichthys indicus and Rhinecanthus

rectangulus were found on massive coral and rubble 53.57 and 46.63%; 20.00 and 80.00% respectively), the former showing preference towards massive coral and the latter towards rubble (Fig. 25 B & 24 A). Of the two, M. indicus had an even distribution. Balistes viridescens (Photo 30) was found on live coral patches (81.40%) and seagrass beds (18.60%) with habitat diversity and evenness of 0.71. Pseudobalistes flavimarginatus was found only on seagrass beds.

Tylosurus spp., Qmobranchus spp., and Bothus pantherinus occurred in low numbers (38, 42 and 12 respectively) on seagrass beds. Trachinous spp. preferred sand flats. Caesionids occurred only twice with approximately 200 individuals on massive coral. All species mentioned above had low habitat diversity and uneven distribution.

Of the 13 chaetodontid species, Chaetodon auriga (Photo 31) was the most abundant species (380 nos) occurring 67 times (Fig. 24 B). With a relatively high habitat diversity (1.63) it indicated preference to massive coral (40.53%) followed by live coral (32.37%) and seagrass (26.58%) with a relatively even distribution of 0.82. Except Chaetodon kleinii (Photo 32) (4 nos) C. lunula (4 nos) and Heniochus monoceros (one) occurring once or twice, other species had a numerical range between 9 and 86. C. xanthocephalus (Photo 33) (86 nos) and C. citrinellus (Photo 34) (65 nos) showed a relatively high habitat diversity (1.36 and 1.55 respectively) with the former indicating an even distribution. C. xanthocephalus preferred live coral (51.16%) followed by seagrass beds (38.37%) while C. citrinellus (65 nos), showed a relatively high habitat

diversity (1.36 and 1.55 respectively) with the former indicating an even distribution. C. xanthocephalus preferred live coral (51.16%) followed by seagrass beds (38.37%) while C. citrinellus preferred massive coral and rubble (40.00 and 46.15% respectively). Chaetodon melannotus (Photo 35) (48 nos), C. trifasciatus (Photo 36) (39 nos) and Heniochus acuminatus (56 nos), were found on the same habitats but with varying preferences; C. melannotus on seagrass beds (77.08%), C. trifasciatus on seagrass, massive coral and live coral (44.64, 30.36 and 48.72% respectively) and H. acuminatus on massive coral (38.46%). C. trifasciatus and H. acuminatus had relatively high habitat diversities of 1.54 and 1.41 respectively. An even distribution was seen in C. kleinii (1.00) and C. falcula (Photo 37) (0.99). C. collare (Photo 38) (42 nos) preferred massive coral (95.25%) while all individuals of C. trifascialis and C. vagabundus (Photo 39, 40) were recorded on live coral zone.

Cirrhites pinnulatus was recorded only once on massive coral while Paracirrhites forsteri (Photo 41) (27 nos) was recorded 11 times, prefering live coral (77.78%). Diodon histrix was mainly found on seagrass beds (73.91%) followed by sand flats (21.74%) while Fistularia petimba (173 nos) were mostly found on seagrass beds (86.13%) with an uneven distribution (0.36). Grammistes sexlineatus (Photo 42) was rare and preferred massive coral zones. Gobiids (117 nos) also accounted for a low diversity and evenness (0.29) preferring rubble zones. Of the two haemulid species, Plectorhinchus orientalis (14 nos) was found to frequent massive coral (78.57%) followed by rubble (21.43%) while P. gibbosus was found only on massive coral zones. All holocentrids, Myripristis murdjan, Sargocentron

spp. and Myripristis adusta were recorded on massive coral zones showing no diversity and evenness of distribution. With a habitat diversity and evenness of 0.74, Kuhlia mugil occured on seagrass (78.57%) and sandflats (21.45%).

Highest number of species (27) were recorded by Labridae. Remarkably abundant was Halichoeres scapularis (Photo 43) (1412 nos) occurring 112 times on all habitats more or less evenly (0.96) with a habitat diversity of 2.23 (Fig. 24 F). It indicated a nearly equal preference towards rubble, sand and seagrass (27.20, 25.21 and 23.51% respectively) followed by massive coral forming 14.09% and live coral forming 9.99% (Fig. 24 D). Other species recording relatively high counts were Halichoeres centiguadrus (Photo 44) (342 nos), Stethojulis albovittata (Photo 45) (271 nos), S. strigiventer (Photo 46) (200 nos) Labroides dimidiatus (124 nos) and Thalassoma hardwicki (116 nos); the first two and last accounted for higher habitat diversity (1.02, 1.53 and 1.23 respectively) while their distribution was uneven. H. centiquadrus (Fig 17 A), L. dimidiatus and T. hardwicki showed preference towards massive coral with proportions of 78.95, 84.68 and 60.34% respectively. T. hardwicki was also found on live coral (34.48%). Among the two species belonging to genus Stethojulis, S. strigiventer was found more on seagrass beds (91.37%) while S. albovittata apart from being present on seagrass beds (61.63%) also occurred on rubble, sand and massive coral (18.08%, 10.33% and 9.96% respectively).

Cheilio inermis (Photo 47) (97 nos) was found mainly on seagrass (86.60%) followed by sandflats (13.40%). Cheilinus trilobatus (Photo 48) (89 nos) preferred massive coral zones (78.65%), though they were found on rubble and sand. Other species mainly preferred seagrass beds; among them were Coris gaimard (60.00%) Hologymnosus doliatus (81.25%), Anampses caeruleopunctatus (Photo 49) (60.00%), and Thalassoma amblycephalum (100%). Coris gaimard had a higher habitat diversity (1.56) and a relatively even distribution (0.78).

Cheilinus undulatus (Photo 50) indicated higher habitat diversity (1.34) and preferred massive coral (64.29%) followed by rubble (28.81%). The distribution however was not even (0.67). Halichoeres marginatus also showed a relatively high habitat diversity (1.26) and preferred, both massive coral and rubble equally (47.06% each). Diversity was low in Gomphosus coeruleus (0.43) with a preference to massive coral (90.91%). Only 4 individuals of Thalassoma herbraicum were found on massive coral and rubble, the distribution being most even (1.00) with a habitat diversity of 1.00. Halichoeres nebulosus (45 nos) and Thalassoma purpureum (3 nos) were observed on rubble (82.22 and 66.67% respectively) followed by massive coral (17.78 and 33.33% respectively).

All individuals of Thalassoma lunare, Novaculichthys taeniourus (Photo 51), Gomphosus varius, Cheilinus chlorurus, C. digrammus, Bodianus axillaris (Photo 52), and Hemigymnus meleapterus (Photo 53) were observed only on massive coral while Coris formosa and Labroides bicolor were found on live coral zone. No diversity was observed and distribution was restricted.

Of the two species of lutjanids, Gnathodentex aureolineatus (303 nos) recorded high counts while it occurred only 5 times. With low diversity and restricted distribution, it indicated preference towards massive coral (99.01%). Monotaxis grandoculis (8 nos) equally represented massive coral and seagrass beds (50.00% each), with a habitat diversity and evenness of 1.00, Malacanthus latovittatus (3 nos), was observed only 2 times on massive coral (66.67%) and seagrass (33.33%). Both species of monocanthids, Alutera scripta (30 nos) and Cantherinus pardalis (5 nos) showed preference towards seagrass (93.33% and 100% respectively) with the former occurring on massive coral (6.67%) recording a diversity and evenness of 0.37. Crenemugil crenilabis (32 nos) and Parapercis hexophthalma (73 nos) preferred sand flats (81.25 and 69.86% respectively). Both species were also found on seagrass (18.75 and 6.85%) with the latter indicating a higher habitat diversity (1.12) forming a proportion of 23.29% on massive coral zone.

Of the 6 species of mullids, Parupeneus barberinus (Photo 54) (351 nos), P. bifasciatus (150 nos) P. macronema (191 nos), and Mulloides, flavolineatus (Photo 55) (206 nos), registered high counts and occurred 25 to 49 times with relatively high habitat diversities (1.57 to 1.94) and evenness of distribution (0.84 to 0.97). All four species mentioned above, indicated a general tendency towards seagrass beds with proportions ranging from 34.67 to 55.83% except in P. barberinus where it was 19.66% while most P. barberinus individuals dominated sand flats (37.61%). P. pleurostigma (Photo 56) (55 nos) also accounted for relatively high diversity (1.42) but was not even in distribution (0.71) with majority of

individuals observed on seagrass (65.45%). P. cyclostomus (Photo 57) was rare and most of the individuals were recorded on massive coral (75.00%).

Gymnothorax undulatus (21 nos) was commonly encountered (15 times). With a relativity higher habitat diversity (1.30) it occurred prominently on rubble (52.38%) followed by live coral (38.10%) and massive coral (9.52%) with a relatively even distribution (0.82). Echinda nebulosa was encountered only once on massive coral. Scolopsis bilineatus (21 nos) preferred rubble (92.86%) while it was also recorded on seagrass beds (7.14%); recording a habitat diversity and evenness of 0.73. Ostraciids were rare in occurrence (3 to 8 times). Lactoria cornuta with a habitat diversity of 1.91 was comparitively even in distribution (0.96) on live coral and seagrass (25.00% each), massive coral (37.50%) and sand flats (12.50%). Platax orbicularis (6 nos) occurred two times with all individuals recorded from massive coral. 31 individuals of Plesiops caeruleolineatus were recorded 4 times, from rubble while Polynemus spp. (44 nos) were evenly distributed (0.98) on sand flats (56.82%) and seagrass beds (43.18%) with a low habitat diversity (0.98).

Fifteen pomacentrids were recorded of which only Abudefduf sexfasciatus indicated high habitat diversity (1.54) but was less even in distribution (0.77), predominating massive coral (45.90%) followed by live coral (36.48%). In terms of abundance, Dascyllus aruanus (Photo 58) (661 nos) and Chromis caerulea (628 nos) ranked first, occurring 28 and 26 times respectively, with low diversity and evenness. They were prominent on live coral (99.39% and 92.20% respectively) and a negligible proportion

represented rubble (D. aruanus) and massive coral (C. caerulea). Among species occuring 24 to 29 times were, Chrysiptera biocellata (321 nos), Pomacentrus trilineatus (306 nos) and P. pavo (299 nos) preferring the rubble zone with proportions of 95.02, 66.01 and 95.32% respectively (Fig. 24 C, 24 D & 25 D). Their representation on other sub-habitats was meagre with a low habitat diversity and evenness, except in P. trilineatus where distribution was nearly even (0.93). With a low diversity and restricted distribution, Plectroglyphidodon phoenixensis (117 nos) recorded higher proportions on rubble (93.16%) followed by massive coral 6.84%.

Pomacentrus sulfureus (117 nos, Fig. 24 E), Stegastes nigricans (25 nos), Pomacentrus spp. (15 nos) and Stegastes lividus (4 nos) were found only on rubble. Of these P. sulfureus occurred more frequently (19 times) while others were observed 1 to 3 times. Amphiprion nigripes (19 nos) was found only on massive coral, while A. chrysogaster (6 nos) was recorded from live coral. Two other species belonging to genus Dascyllus, D. trimaculatus (172 nos) and D. reticulatus (133 nos) were observed on live coral.

A single species of pomacanthid, Centropyge multispinis (366 nos) preferred live coral (95.08%) occurring 26 times while Scarus spp. recorded the highest number of individuals (3472 nos) from seagrass beds (50.46%) and massive coral (25.31%) followed by rubble (17.86%) (Fig. 23 D & C). The distribution, however, was relatively uneven (0.72) while habitat diversity was high (1.68).

Among the 3 species of scorpaenids, Dendrochious zebra (48 nos) and Pterois miles (26 nos) showed higher habitat diversities of 1.10 and 1.38 respectively the latter being relatively even in distribution (0.81). D. zebra preferred live coral (68.75%) followed by sand flats (25.00%) and were recorded from seagrass beds. P. miles preferred seagrass (57.69%) followed by massive coral (26.92%) and sand flats (15.38%). Pterois radiata had an even distribution (0.92) with a low habitat diversity showing preference to massive coral (66.67%) and live coral (33.33%).

Among serranids, Epinephelus spp. frequently occurred (48 times) recording 144 individuals, prefering massive coral (45.83%) and live coral (40.97%) followed by rubble (13.19%). It had a habitat diversity of 1.43 and a fairly even distribution (0.90). Cephalopholis argus was found in a greater proportion (84.62%) on massive coral followed by rubble (15.38%) with a relatively low diversity and evenness (0.61). Only two individuals of Siganus stellatus were observed on seagrass beds. An even distribution (0.99) was seen in Sphyraena spp. (69 nos) that was observed on seagrass (55.07%) and sand flats (44.93%). Tetraodon nigropunctatus (34 nos) had a relatively high habitat diversity (1.23) showing preference towards live coral (67.57%) while it was also recorded on massive coral (14.71%) and seagrass (17.65%). Canthigaster margaritata (25 nos) had a low habitat diversity and was mostly found on massive coral (92.00%) though a few individuals inhabited seagrass (8.00%). Therapon jarbua (40 nos) was recorded 9 times mostly on sand flats (90.00%) while Zanclus canescens (Photo 59) (48 nos) preferred massive coral (60.42%) followed by seagrass (39.58%) with a relatively high habitat diversity of 1.42.

Table 28. Habitat preference as indicated by frequency of occurrence and percentage abundance on the five sub-habitats - live coral (L), massive coral (M), rubble (R), sand (S) and seagrass beds (SG); pooled frequency of occurrence (FO) and total abundance (TA), habitat diversity (H') and evenness indices (J') of fish species encountered during the censuses.

SPECIES	FO	TA	FREQUENCY OF OCCURENCE					PERCENTAGE ABUNDANCE					H'	J'
			L	M	R	S	SG	L	M	R	S	SG		
ACANTHURIDAE														
1. Acanthurus triostegus	58	565	-	9	15	20	14	-	15.58	23.36	30.44	30.62	1.95	0.98
2. Acanthurus spp.	28	224	-	8	5	-	15	-	31.25	19.20	-	49.55	1.48	0.93
3. Acanthurus leucosternon	26	174	1	17	-	2	6	0.57	87.93	-	3.45	8.05	0.67	0.34
4. Acanthurus lineatus	10	61	-	7	3	-	-	-	83.61	16.39	-	-	0.63	0.63
5. Naso unicornis	10	29	-	2	2	-	6	-	10.34	13.79	-	75.86	1.03	0.65
6. Zebrasoma veliferum	10	23	-	1	-	-	9	-	8.70	-	-	91.30	0.43	0.43
7. Naso lituratus	5	9	-	3	2	-	-	-	33.33	66.67	-	-	0.92	0.92
8. Naso brevirostris	3	6	-	1	-	-	2	-	16.67	-	-	83.33	0.66	0.66
APOGONIDAE														
1. Apogon spp.	3	53	-	3	-	-	-	-	100.00	-	-	-	0.00	0.00
2. Apogon fraenatus	2	14	-	-	1	-	1	-	-	42.86	-	57.14	1.00	1.00
3. Apogon taeniophorus	1	6	-	-	-	-	1	-	-	-	-	100.00	0.00	0.00
BALISTIDAE														
1. Rhinecanthus aculeatus	31	175	4	17	21	1	1	2.86	29.14	66.29	1.14	0.57	1.21	0.52
2. Balistes viridescens	18	43	14	-	-	-	4	81.40	-	-	-	18.60	0.71	0.71
3. Melichthys indicus	9	28	-	4	5	-	-	-	53.57	46.43	-	-	1.00	1.00
4. Rhinecanthus rectangulus	8	15	-	3	5	-	-	-	20.00	80.00	-	-	0.94	0.94
5. Pseudobalistes flavimarginatus	3	12	-	-	-	-	3	-	-	-	-	100.00	0.00	0.00
6. Sufflamen bursa	1	1	-	1	-	-	-	-	100.00	-	-	-	0.00	0.00

Contd.....

SPECIES	FO	TA	L	M	R	S	SG	L	M	R	S	SG	H'	J'
BELONIDAE														
Tylosurus spp.	4	38	-	-	-	-	4	-	-	-	-	100.00	0.00	0.00
BLENNIIDAE														
Omobranchus spp.	4	42	-	-	-	-	4	-	-	-	-	100.00	0.00	0.00
BOTHIDAE														
Bothus pantherinus	7	12	-	-	-	1	6	-	-	-	8.33	91.67	0.40	0.40
CAESIONIDAE														
Caesio spp.	2	200	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
CARANGIDAE														
Trachinotus spp.	5	16	-	-	-	5	-	-	--	-	100.00	-	0.00	0.00
CHAETODONTIDAE														
Chaetodon auriga	67	380	24	24	1	-	18	32.37	40.53	0.53	-	26.58	1.63	0.82
Chaetodon xanthocephalus	23	86	12	4	-	-	7	51.16	10.47	-	-	38.37	1.36	0.86
Chaetodon citrinellus	22	65	2	11	8	-	1	10.77	40.00	46.15	-	3.08	1.55	0.78
Chaetodon melannotus	13	48	3	1	-	-	9	18.75	4.17	-	-	77.08	0.94	0.59
Heniochus acuminatus	13	56	3	3	-	-	7	25.00	30.36	-	-	44.46	1.54	0.97
Chaetodon trifasciatus	12	39	5	6	-	-	1	48.72	38.46	-	-	12.82	1.41	0.89
Chaetodon falcula	8	12	4	4	-	-	-	58.33	41.67	-	-	-	0.99	0.99
Chaetodon collare	7	42	-	6	-	-	1	-	95.24	-	-	4.76	0.29	0.29
Chaetodon trifascialis	5	9	5	-	-	-	-	100.00	-	-	-	-	0.00	0.00
Chaetodon vagabundus	5	13	5	-	-	-	-	100.00	-	-	-	-	0.00	0.00
Chaetodon kleinii	2	4	-	1	-	-	1	-	50.00	-	-	50.00	1.00	1.00
Chaetodon lunula	2	4	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
Heniochus monoceros	1	1	-	1	-	-	-	-	100.00	-	-	-	0.00	0.00

Contd.....

SPECIES	FO	TA	L	M	R	S	SG	L	M	R	S	SG	H'	J'
CIRRHITIDAE														
Paracirrhites forsteri	11	27	7	4	-	-	-	77.78	22.22	-	-	-	0.76	0.76
Cirrhites pinnulatus	1	1	-	1	-	-	-	-	100.00	-	-	-	0.00	0.00
DIODONTIDAE														
Diodon histrix	15	23	-	1	-	5	9	-	4.35	-	21.74	73.91	0.99	0.62
FISTULARIIDAE														
Fistularia petimba	19	173	1	1	3	3	11	0.58	6.94	347	2.88	86.13	0.83	0.36
GRAMMISTIDAE														
Grammistes sexlineatus	4	4	1	3	-	-	-	25.00	75.00	-	-	-	0.81	0.81
GOBIIDAE														
Gobiids	10	117	-	-	9	1	-	-	-	94.87	5.13	-	0.29	0.29
HAEMULIDAE														
Plectorhinchus orientalis	10	14	-	7	3	-	-	-	78.57	21.43	-	-	0.74	0.74
Plectorhinchus gibbosus	2	4	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
HOLOCENTRIDAE														
1. Myripristis murdjan	3	7	-	3	-	-	-	-	100.00	-	-	-	0.00	0.00
2. Sargocentron spp.	2	16	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
3. Myripristis adusta	2	2	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
KUHLIDAE														
Kuhlia mugil	6	182	-	-	-	3	3	-	-	-	21.43	78.57	0.74	0.74
LABRIDAE														
1. Halichoeres scapularis	112	1412	21	21	24	26	20	9.99	14.09	27.20	25.21	23.51	2.23	0.96
2. Halichoeres centiquadrus	36	342	6	22	6	-	2	7.31	78.95	11.99	-	1.75	1.02	0.51
3. Stethojulis albovittata	34	271	-	4	5	8	17	-	9.96	18.08	10.33	61.63	1.53	0.77
4. Labroides dimidiatus	24	124	2	17	5	-	-	1.61	84.68	13.71	-	-	0.71	0.45

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SPECIES	FO	TA	L	M	R	S	SG	L	M	R	S	SG	H'	J'
5. Cheilio inermis	22	97	-	-	-	6	15	-	-	-	13.40	86.60	0.17	0.17
6. Cheilinus trilobatus	19	89	-	11	6	-	2	-	78.65	17.98	-	3.37	0.86	0.54
7. Stethojulis strigiventer	19	200	-	2	1	-	16	-	6.60	2.03	-	91.37	0.50	0.32
8. Thalassoma hardwicki	19	116	4	12	-	2	1	34.48	60.34	-	4.32	0.86	1.23	0.62
9. Coris gaimard	18	30	2	6	2	-	8	10.00	20.00	10.00	-	60.00	1.56	0.78
10. Cheilinus undulatus	15	42	1	9	4	-	1	2.38	64.29	23.81	-	9.52	1.34	0.67
11. Thalassoma lunare	11	26	-	11	-	-	-	-	100.00	-	-	-	0.00	0.00
12. Hologymnosus doliatus	9	16	-	-	2	-	7	-	-	18.75	-	81.25	0.71	0.71
13. Novaculichthys taeniourus	8	22	-	8	-	-	-	-	100.00	-	-	-	0.00	0.00
14. Anampses caeruleopunctatus	7	69	-	4	-	-	3	-	40.00	-	-	60.00	0.55	0.55
15. Halichoeres marginatus	7	17	-	4	-	-	1	-	47.06	47.06	-	5.88	1.26	0.79
16. Gomphosus coeruleus	6	11	-	5	-	-	1	-	90.91	-	-	9.09	0.43	0.43
17. Gomphosus varius	6	20	-	6	-	-	-	-	100.00	-	-	-	0.00	0.00
18. Halichoeres nebulosus	5	45	-	1	4	-	-	-	17.78	82.22	-	-	0.67	0.67
19. Cheilinus chlorurus	3	5	-	3	-	-	-	-	100.00	-	-	-	0.00	0.00
20. Cheilinus digrammus	3	6	-	3	-	-	-	-	100.00	-	-	-	0.00	0.00
21. Thalassoma herbraicum	3	4	-	1	2	-	-	-	50.00	50.00	-	-	1.00	1.00
22. Thalassoma purpureum	3	3	-	1	2	-	-	-	33.33	66.67	-	-	0.92	0.92
23. Bodianus axillaris	2	2	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
24. Hemigymnus melapterus	2	2	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
25. Coris formosa	1	1	1	-	-	-	-	100.00	-	-	-	-	0.00	0.00
26. Labroides bicolor	1	1	1	-	-	-	-	100.00	-	-	-	-	0.00	0.00
27. Thalassoma amblycephalum	1	2	-	-	-	-	1	-	-	-	-	100.00	0.00	0.00
LETHRINIDAE														
Gnathodentex aureolineatus	5	303	-	3	-	2		-	99.01	-	0.99	-	0.08	0.08
Monotaxis grandoculis	5	8	-	3	-	-	2	-	50.00	0	0	50.00	1.00	1.00

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SPECIES	FO	TA	L	M	R	S	SG	L	M	R	S	SG	H'	J'
MALACANTHIDAE														
Malacanthus latovittatus	2	3	-	1	-	-	1	-	66.67	-	-	33.33	0.92	0.92
MONOCANTHIDAE														
Alutera scripta	13	30	-	2	-	-	11	-	6.67	-	-	93.33	0.37	0.37
Cantherinus pardalis	4	5	-	-	-	-	4	-	-	-	-	100.00	0.00	0.00
MUGILIDAE														
Crenemugil crenilabis	7	32	-	-	-	5	2	-	-	-	81.25	18.75	0.71	0.71
MUGILOIDIDAE														
Parapercis hexophthalma	21	73	-	5	-	14	2	-	23.29	-	69.86	6.85	1.12	0.71
MULLIDAE														
1. *Parupeneus barberinus*	49	351	-	10	10	18	11	-	23.93	18.80	37.61	19.66	1.94	0.97
2. *Parupeneus bifasciatus*	33	150	-	9	8	7	9	-	24.67	25.33	15.33	34.67	1.94	0.97
3. *Parupeneus macronema*	33	191	-	10	-	10	13	-	29.32	-	28.27	42.41	1.57	0.99
4. *Mulloides flavolineatus*	25	206	-	2	5	6	12	-	14.56	9.71	19.90	55.83	1.67	0.84
5. *Parupeneus pleurostigma*	13	55	-	2	3	1	7	-	16.36	14.55	3.64	65.45	1.42	0.71
6. *Parupeneus cyclostomus*	3	8	-	2	-	-	1	-	75.00	-	-	25.00	0.81	0.81
MURAENIDAE														
1. *Gymnothorax undulatus*	15	21	6	1	8	-	-	38.10	9.52	52.38	-	-	1.30	0.82
2. *Echinda nebulosa*	1	1	-	1	-	-	-	-	100.00	-	-	-	0.00	0.00
NEMIPTERIDAE														
Scolopsis bilineatus	8	28	-	-	7	-	1	-	-	92.86	-	7.14	0.73	0.73
OSTRACIIDAE														
Lactoria cornuta	8	8	2	3	-	1	2	25.00	37.50	-	12.50	25.00	1.91	0.96
Ostracion meleagris	3	4	2	-	-	-	1	50.00	-	-	-	50.00	1.00	1.00

Contd.....

	FO	TA	L	M	R	S	SG	L	M	R	S	SG	H'	J'
PLATACIDAE														
Platax orbicularis	2	6	-	2	-	-	-	-	100.00	-	-	-	0.00	0.00
PLESIOPIDAE														
Plesiops caerulolineatus	4	31	-	-	4	-	-	-	-	100.00	-	-	0.00	0.00
POLYNEMIDAE														
Polynemus spp.	12	44	-	-	-	9	3	-	-	-	56.82	43.18	0.98	0.98
POMACENTRIDAE														
Abudefduf sexfasciatus	34	244	10	15	1	-	8	36.48	45.90	1.23	-	16.39	1.54	0.77
Chrysiptera biocellata	29	321	1	6	22	-	-	0.93	4.05	95.02	-	-	0.33	0.21
Dascyllus aruanus	28	661	27	-	1	-	-	99.39	-	0.61	-	-	0.08	0.08
Chromis caerulea	26	628	23	3	-	-	-	92.20	7.80	-	-	-	0.78	0.78
Pomacentrus trilineatus	26	306	-	2	24	-	-	-	33.99	66.01	-	-	0.93	0.93
Pomacentrus pavo	24	299	2	3	19	-	-	1.34	3.34	95.32	-	-	0.29	0.18
Pomacentrus sulfureus	19	117	-	-	19	-	-	-	-	100.00	-	-	0.00	0.00
Dascyllus trimaculatus	17	172	17	-	-	-	-	100.00	-	-	-	-	0.00	0.00
Dascyllus reticulatus	14	133	14	-	-	-	-	100.00	-	-	-	-	0.00	0.00
Plectroglyphidodon phoenixensis	14	117	-	2	12	-	-	-	6.84	93.165	-	-	0.37	0.37
Amphiprion nigripès	4	19	-	4	-	-	-	-	100.00	-	-	-	0.00	0.00
Stegastes nigricans	3	25	-	-	3	-	-	-	-	100.00	-	-	0.00	0.00
Amphiprion chrysogaster	2	6	2	-	-	-	-	100.00	-	-	-	-	0.00	0.00
Pomacentrus spp.	2	15	-	-	2	-	-	-	-	100.00	-	-	0.00	0.00
Stegastes lividus	1	4	-	-	1	-	-	-	-	100.00	-	-	0.00	0.00
POMACANTHIDAE														
Centropyge multispinis	26	366	25	1	-	-	-	95.08	4.92	-	-	-	0.29	0.29
SCARIDAE														
Scarus spp.	38	3472		15	8	5	18		25.37	17.86	5.94	50.83	1.68	0.72

Contd.....

SPECIES	FO	TA	L	M	R	S	SG	L	M	R	S	SG	H'	J'
SCORPAENIDAE														
1. Dendrochirus zebra	20	48	13	-	-	5	2	68.75	-	-	25.00	6.25	1.10	0.69
2. Pterois miles	17	26	-	6	-	4	7	-	26.92	-	15.38	57.69	1.38	0.87
3. Pterois radiata	3	3	1	2	-	-	-	33.33	66.67	-	-	-	0.92	0.92
SERRANIDAE														
1. Epinephelus spp.	48	144	17	12	3	-	-	40.97	45.83	13.19	-	-	1.43	0.90
2. Cephalopholis argus	13	26	4	9	-	-	-	15.38	84.62	-	-	-	0.61	0.61
SIGANIDAE														
Siganus stellatus	1	2	-	-	-	-	1	-	-	-	-	100.00	0.00	0.00
SPHYRAENIDAE														
Sphyraena spp.	10	69	-	-	-	7	3	-	-	-	44.93	55.07	0.99	0.99
TETRAODONTIDAE														
1. Tetraodon nigropunctatus	12	34	5	2	-	-	5	67.65	14.71	-	-	17.65	1.23	0.78
2. Canthigaster margaritata	6	25	-	5	-	-	1	-	92.00	-	-	8.00	0.40	0.40
THERAPONIDAE														
Therapon jarbua	9	40	-	-	-	8	1	-	-	-	90.00	10.00	0.47	0.47
ZANCLIDAE														
Zanclus canescens	13	48	-	7	-	-	6	-	60.42	-	-	39.58	1.42	0.90

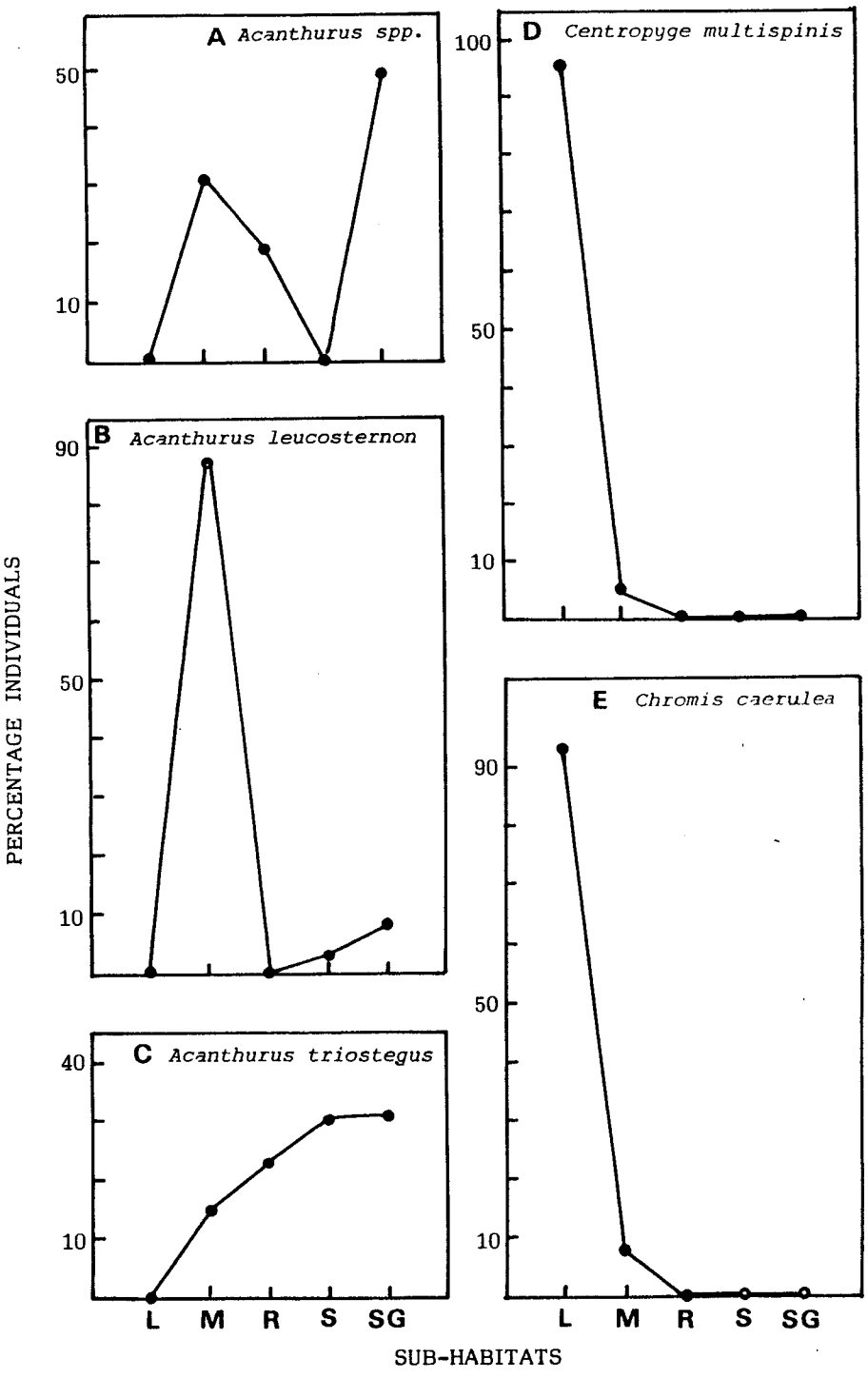


Figure 23. Percentage of individuals of some dominant fish species on live coral (L), massive coral (M), rubble (R), sand (S) and seagrass beds (SG).

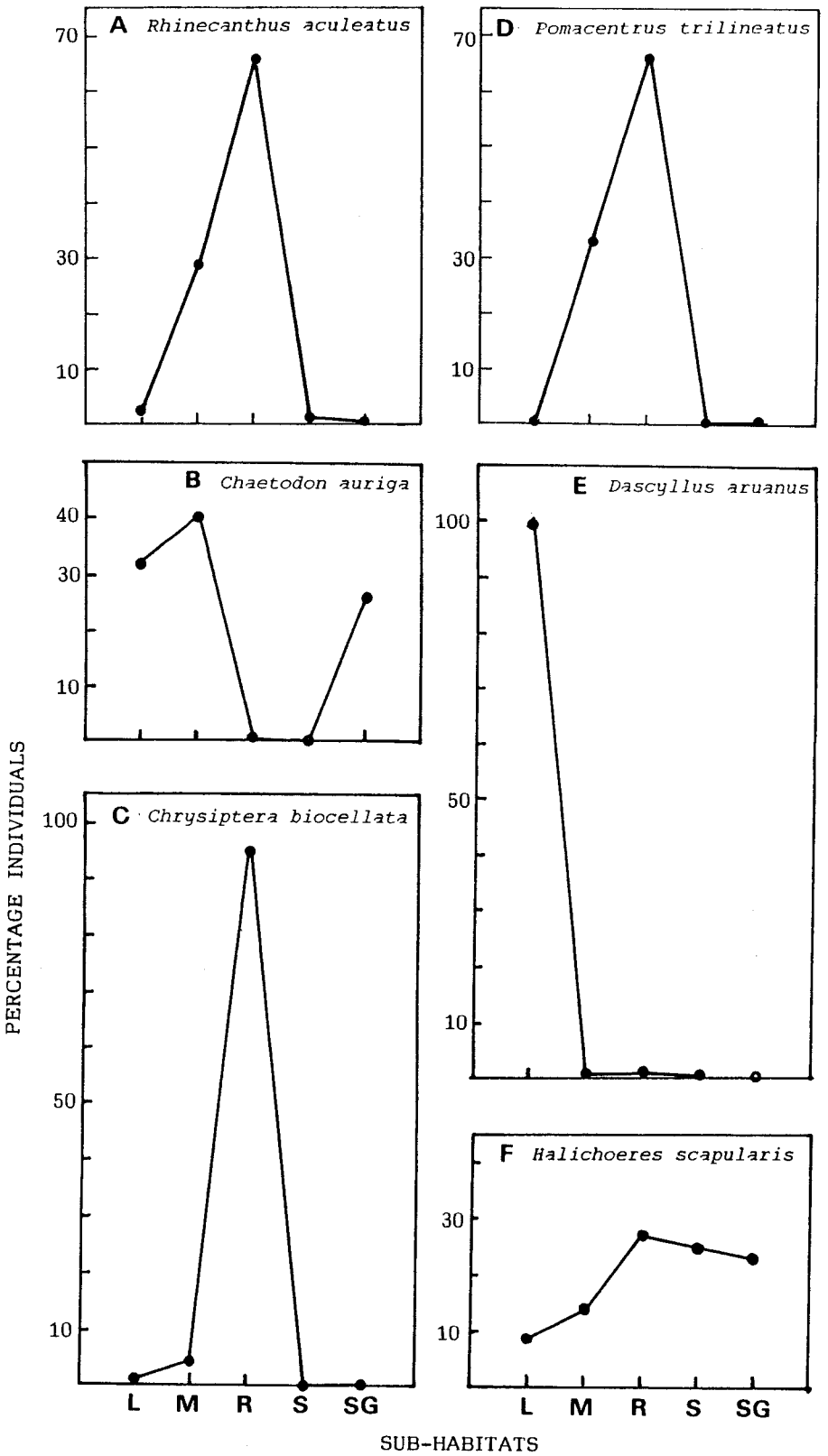


Figure 24. Percentage of individuals of some dominant fish species on live coral (L), massive coral (M), rubble (R), sand (S) and seagrass beds (SG).

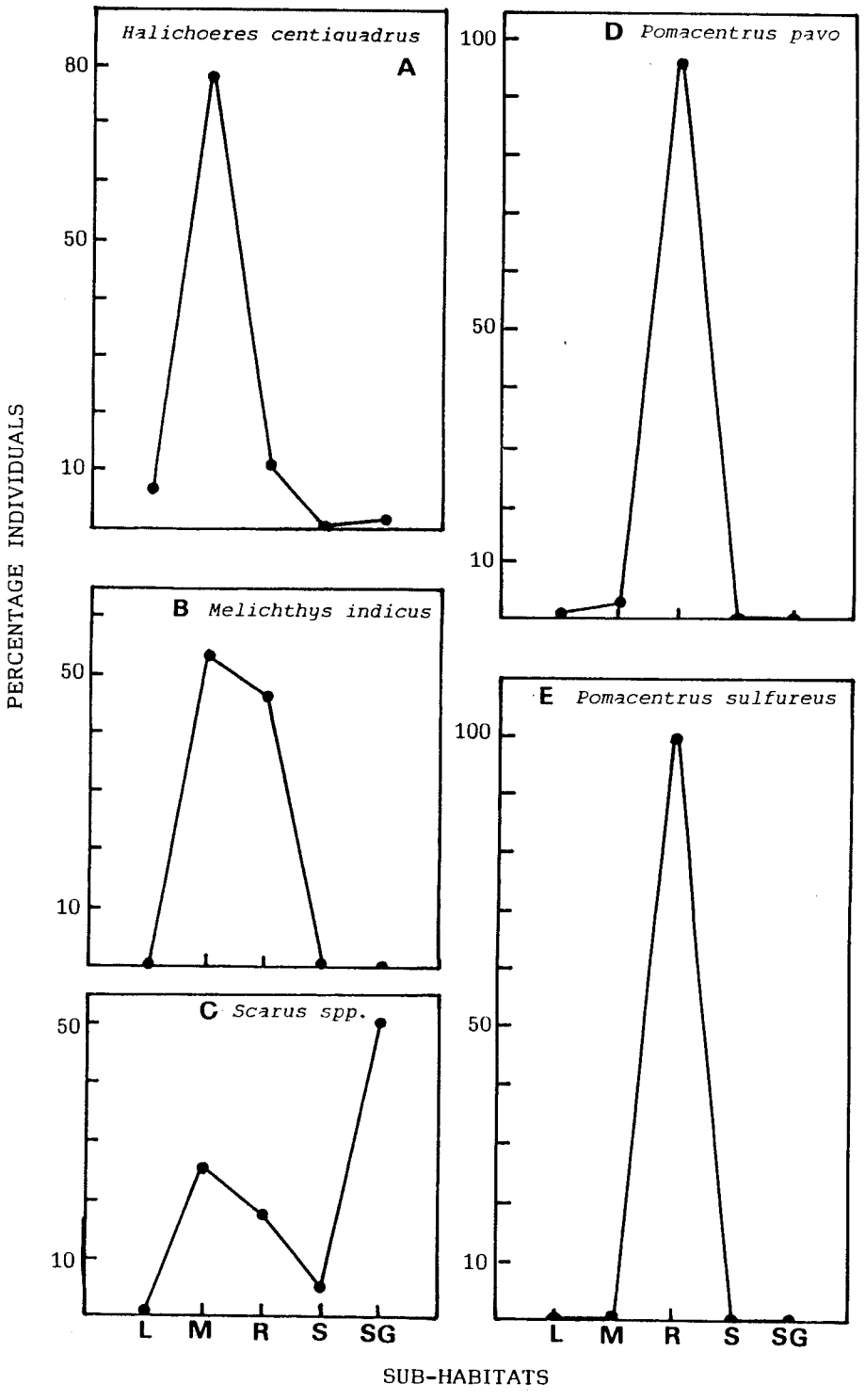


Figure 25. Percentage of individuals of some dominant fish species on live coral (L), massive coral (M), rubble (R), sand (S) and seagrass beds (SG).

4. Presence or absence of species

All species recorded from the five sub-habitats and the reef slope are presented family-wise, in Figure 26.

Acanthurus leucosternon and A. triostegus had a wider distribution, showing presence on 5 regions. A. leucosternon was absent on rubble while A. triostegus was absent from live coral and rubble. Acanthurus spp. and Naso unicornis had similar distribution but did not inhabit live coral and sand. A. lineatus and Naso lituratus were encountered on massive coral, rubble and reef slope, while Naso brevirostris and Zebrasoma veliferum were observed on massive coral, seagrass and reef slope. Naso vlamingi occurred only on reef slopes, where, all species of Acanthuridae recorded were present.

Apogonids were typically absent from live coral and sand flats but occurred in all other regions. Among balistids only Rhinecanthus aculeatus had a wider distribution, showing presence on all 6 regions. Melichthys indicus and Rhinecanthus rectangulus were present on massive coral, rubble and reef slope. Among all balistids only Balistes viridescens inhabited live coral apart from being present on seagrass and reef slope. R. aculeatus, B. viridescens and Pseudobalistes flavimarginatus were the only three species inhabiting seagrass beds. All other species were confined to reef slope except Sufflamen bursa which was also found on massive coral.

Tylosurus spp. and Omobranchus spp. were recorded only on seagrass beds. Bothus pantherinus, Crenemugil crenilabis, Kuhlia mugil, Polynemus spp., Sphyraena spp. and Therapon jarbua were recorded only from seagrass beds and sand flats. Caesio spp. and Elagatis pinnulatus were found on reef slopes with the former also inhabiting the massive coral zone. Trachinotus spp. was found only on sand flats.

Chaetodon auriga and C. citrinellus indicated a wider distribution amonst 18 species recorded. They were absent on sand flats. C. melannotus, C. trifasciatus, C. xanthocephalus and Heniochus acuminatus inhabited live coral, massive coral, seagrass and reef slope. C. collare and C. falcula also had a similar distribution but the former was absent from live coral while the latter was absent on seagrass beds. Apart from being present on massive coral, C. kleinii was the only species absent on the reef slope while all chaetodontids represented the reef slope. C. lunula and Heniochus monoceros were present on massive coral and the reef slope. Other species recorded were found exclusively on the reef slope except Chaetodon trifascialis which was recorded on live coral zone. All chaetodontids were absent on sand flats.

Paracirrhites forsteri, Cirrhites pinnulatus, Diodon histrix and Grammistes sexlineatus were present on live coral and massive coral apart from being present on the reef slope. Fistularia petimba was present on all five sub-habitats but typically absent from reef slope. Gobiids were recorded only from rubble and sand. Both haemulid species,

Plectorhinchus orientalis and P. gibbosus had similar distribution. P. orientalis was also found on rubble. All holocentrids were recorded from massive coral and reef slope.

Halichoeres scapularis was encountered on all regions while Cheilinus undulatus, Coris gaimard, and Halichoeres centiguadrus had a relatively wider distribution but were absent from sand flats. A similar trend was seen in Stethojulis albovittata and Thalassoma hardwicki except that they were absent on live coral and sand Labroides dimidiatus was not recorded on sand and seagrass. Anampses caeruleopunctatus and Gomphosus coeruleus showed similar habitat distribution with presence on massive coral, seagrass and reef slope. Halichoeres nebulosus was also found on 3 sub-habitats, namely, massive coral, rubble, and reef slope. While presence on rubble and seagrass was common to Hologymnosus doliatus and Stethojulis strigiventer, occurrence on reef slope in the former and on massive coral in the latter was also observed. Thalassoma herbraicum, T. purpureum, Bodianus axillaris and Cheilinus chlorurus had similar distribution, with an exception in the two species of genus Thalassoma that were also found on rubble. Cheilio inermis was observed exclusively on sand and seagrass. Coris formosa was recorded from live coral and reef slope. The massive coral zone and reef slope were common habitats for Gomphosus varius, Labroides bicolor, Novaculichthys taeniourus and Thalassoma lunare while T. amblycephalum was recorded only from seagrass and reef slope. Among the labrids, single habitat inhabitants were Cheilinus chlorurus and Hemigymnus melapterus. Of the 27 labrids

recorded, only 4 species, namely, Cheilinus digrammus, Cheilio inermis, Hemigymnus melapterus and Stethojulis strigiventer were absent from the reef slope.

Regions of massive coral, seagrass and reef slope were common for Alutera scripta, Malacanthus latovittatus, and Monotaxis grandoculis. Gnathodentex aureolineatus was absent on seagrass but found on sand flats, massive coral and reef slope. Cantherinus pardalis was present on seagrass and reef slope. Parapercis hexophthalma did not inhabit live coral and rubble.

Of the 6 species of mullids Parupeneus macronema and P. cyclostomus indicated a relatively low distributional range with their absence on live coral and rubble (common to both) and sand flats in the latter. All other species recorded in the family were typically absent on live coral but present in all other regions.

Gymnothorax undulatus was present in most of the regions except on sand flats and seagrass. Gymnothorax spp. and Echinda zebra were present on the reef slope while the latter was also found on massive coral. Scolopsis bilineatus was present on rubble, seagrass and reef slope while Plesiops caeruleolineatus was exclusively found on rubble. Of the two ostraciid species, Lactoria cornuta was absent only on rubble. Ostracion meleagris was found on live coral, seagrass and reef slope. Platax orbicularis was observed on massive coral and reef slope.

Among the pomacentrids, Abudefduf sexfasciatus and Chrysiptera biocellata had relatively wider distribution range with the former absent

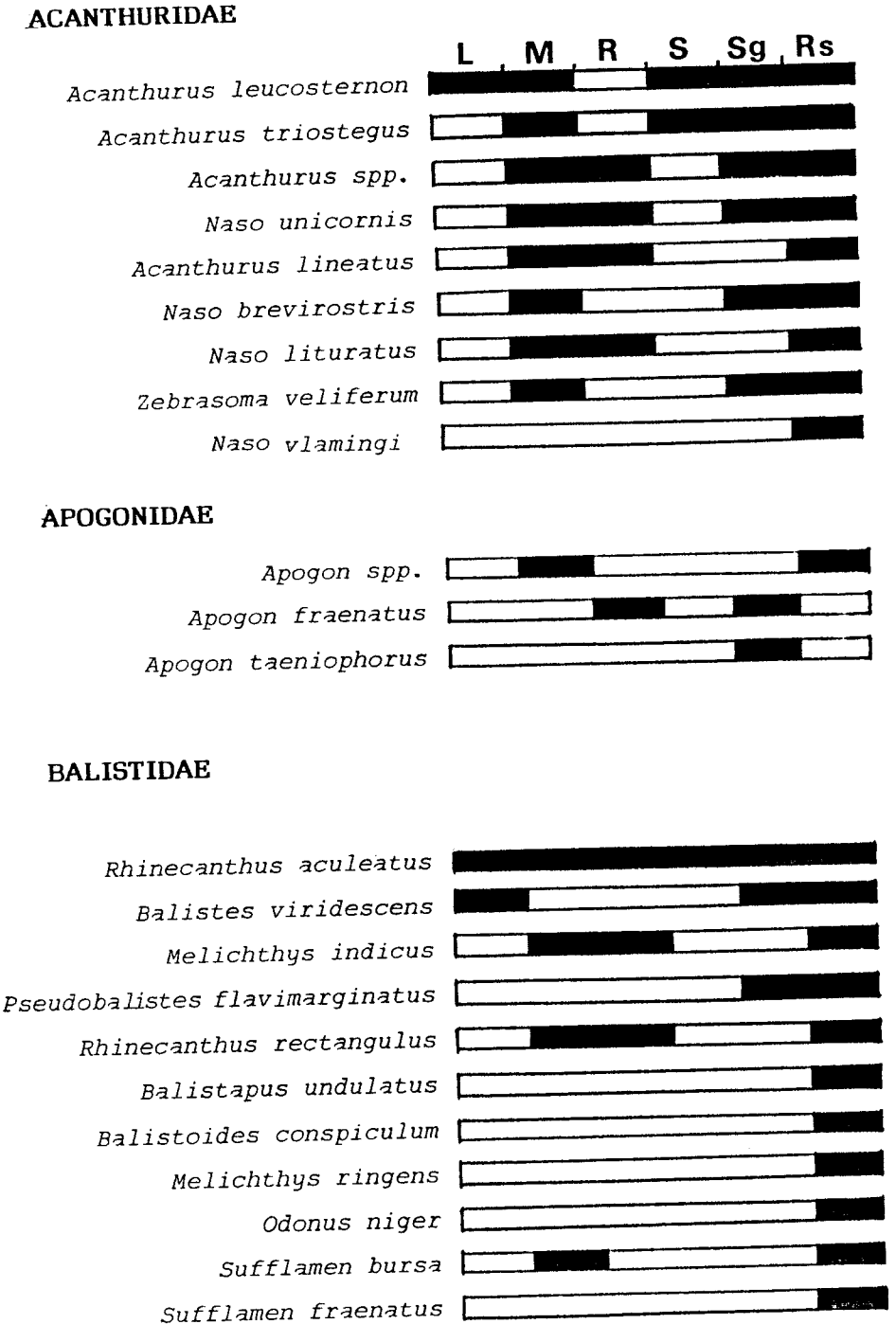
on sand and the latter on sand and seagrass. Chromis caerulea was found on live coral, massive coral and reef slope. Dascyllus aruanus, D. reticulatus and D. trimaculatus were observed on live coral and reef slope. D. aruanus was also found on rubble. Plectroglyphidodon phoenixensis was recorded on massive coral, rubble and reef slope while Pomacentrus pavo inhabited only live coral, massive coral and rubble. Amphiprion nigripes was recorded only on massive coral and reef slope while A. chrysogaster was found only on live coral. Pomacentrus spp. occurred on rubble and reef slope while Pomacentrus trilineatus was recorded from rubble and massive coral. Exclusive rubble dwellers were Pomacentrus sulfureus, Stegastes lividus and S. nigricans. Chromis dimidiata was observed only from the reef slope.

All five species of pomacanthids recorded were found exclusively on the reef slope except Centropyge multispinis which was recorded from live and massive coral zones. Scarids were encountered in all regions. Pterois miles was absent from live coral and rubble while Dendrochirus zebra was absent from massive coral, rubble and reef slope. Pterois radiata was recorded only on live coral and massive coral.

Epinephelus spp. was found on all regions except on seagrass and sand. Cephalopholis argus was absent on rubble, sand and seagrass. Other species recorded were observed exclusively on reef slope. Siganus stellatus was found only on seagrass beds. Of the three tetradontid species, Tetraodon nigropunctatus represented more habitats (Live coral, massive coral and seagrass beds) while Canthigaster margaritata was found

Figure 26. Presence or absence of fish species on the five sub-habitats, - live coral (L), massive coral (M), rubble (R), sand (S), seagrass beds (SG); and the reef slope (RS).

Present Absent



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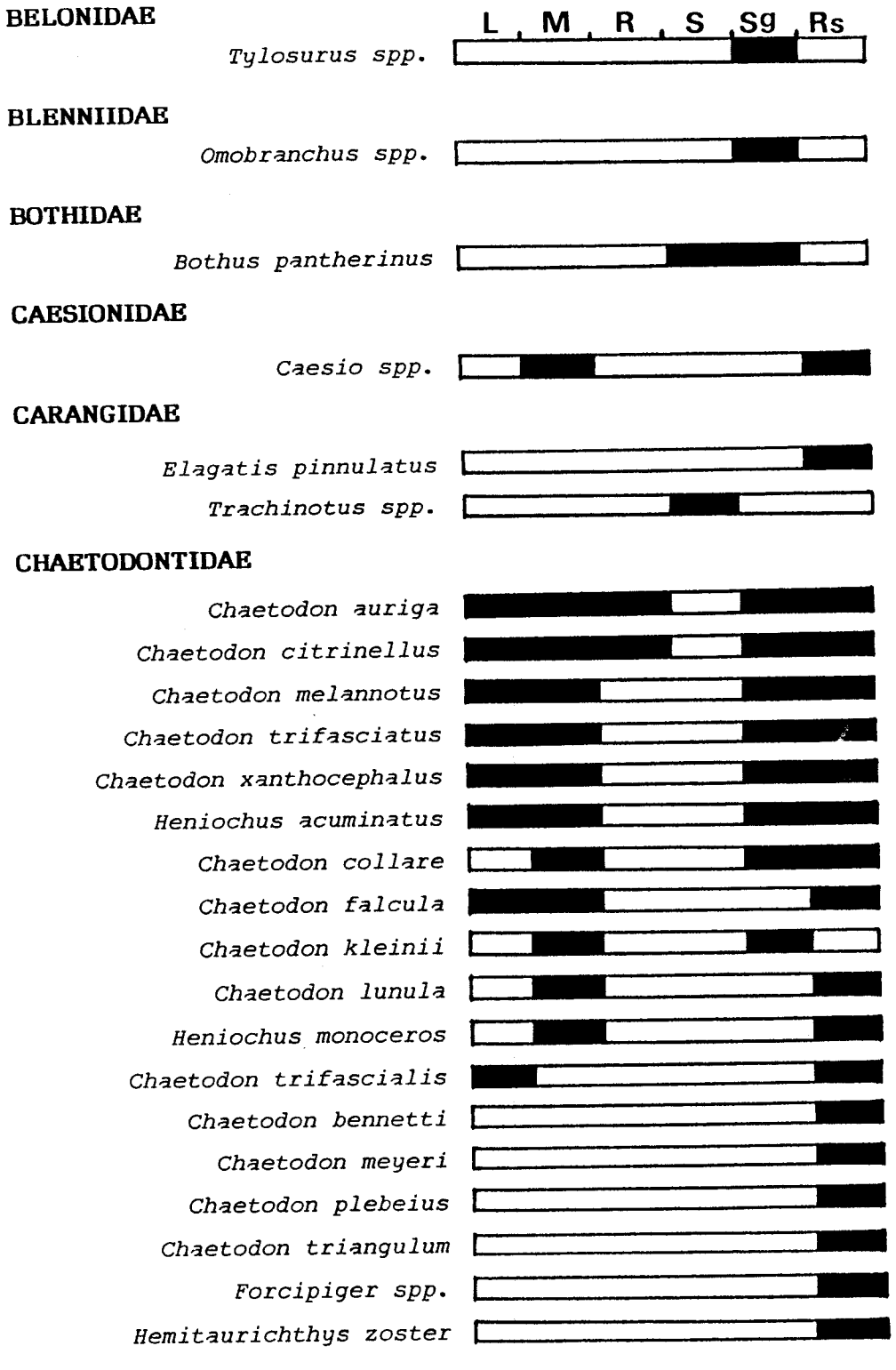
L M R S Sg Rs
BELONIDAE
Tylosurus spp.
BLENNIIDAE
Omobranchus spp.
BOTHIDAE
Bothus pantherinus
CAESIONIDAE
Caesio spp.
CARANGIDAE
Elagatis pinnulatus
Trachinotus spp.
CHAETODONTIDAE
Chaetodon auriga
Chaetodon citrinellus
Chaetodon melannotus
Chaetodon trifasciatus
Chaetodon xanthocephalus
Heniochus acuminatus
Chaetodon collare
Chaetodon falcula
Chaetodon kleinii
Chaetodon lunula
Heniochus monoceros
Chaetodon trifascialis
Chaetodon bennetti
Chaetodon meyeri
Chaetodon plebeius
Chaetodon triangulum
Forcipiger spp.
Hemitaurichthys zoster
CIRRHITIDAE
Paracirrhites forsteri
Cirrhites pinnulatus

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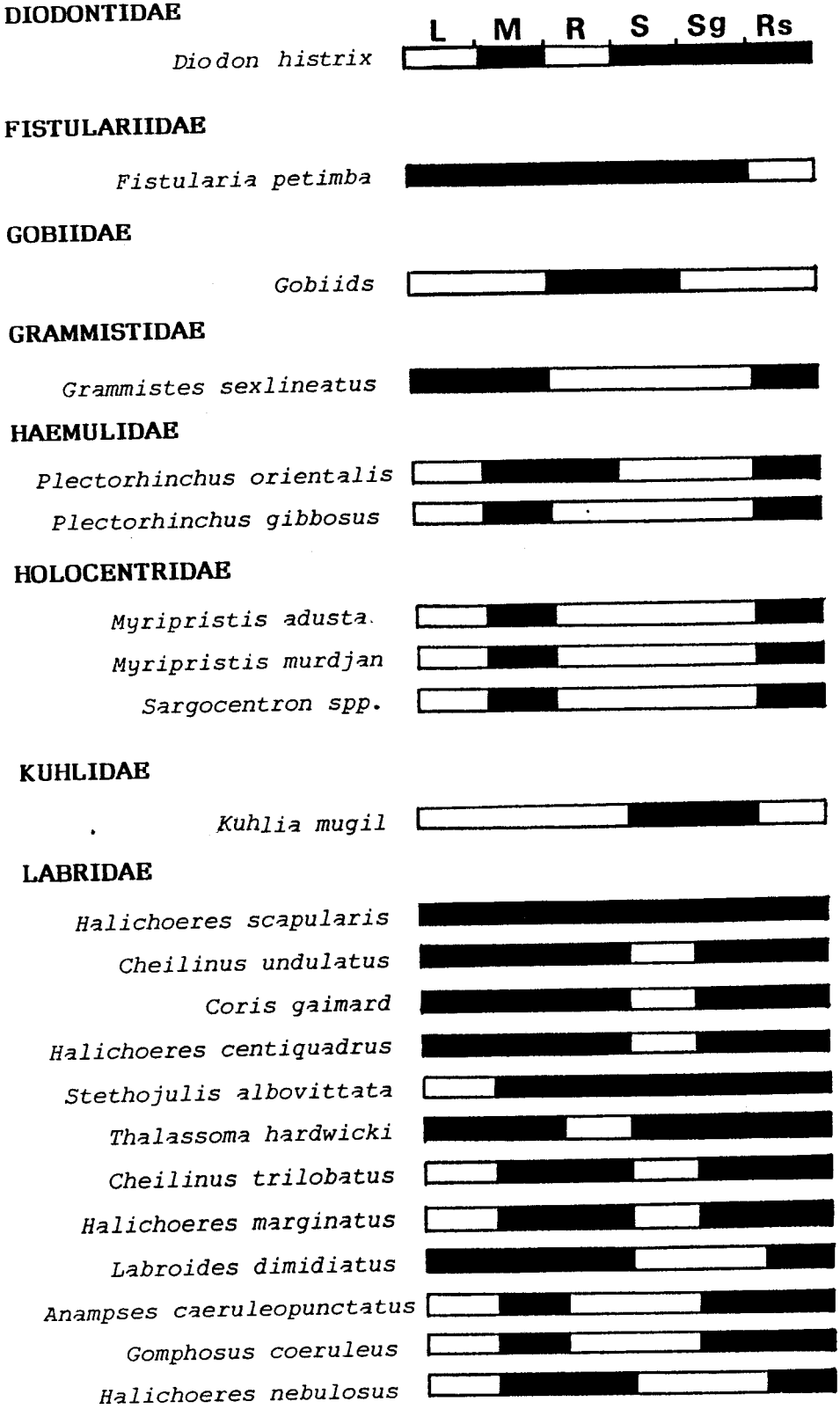
DIODONTIDAE
L M R S Sg Rs
Diodon histrix
FISTULARIIDAE
Fistularia petimba
GOBIIDAE
Gobiids
GRAMMISTIDAE
Grammistes sexlineatus
HAEMULIDAE
Plectorhinchus orientalis
Plectorhinchus gibbosus
HOLOCENTRIDAE
Myripristis adusta
Myripristis murdjan
Sargocentron spp.
KUHLIDAE
Kuhlia mugil
LABRIDAE
Halichoeres scapularis
Cheilinus undulatus
Coris gaimard
Halichoeres centiquadrus
Stethojulis albovittata
Thalassoma hardwicki
Cheilinus trilobatus
Halichoeres marginatus
Labroides dimidiatus
Anampses caeruleopunctatus
Gomphosus coeruleus
Halichoeres nebulosus

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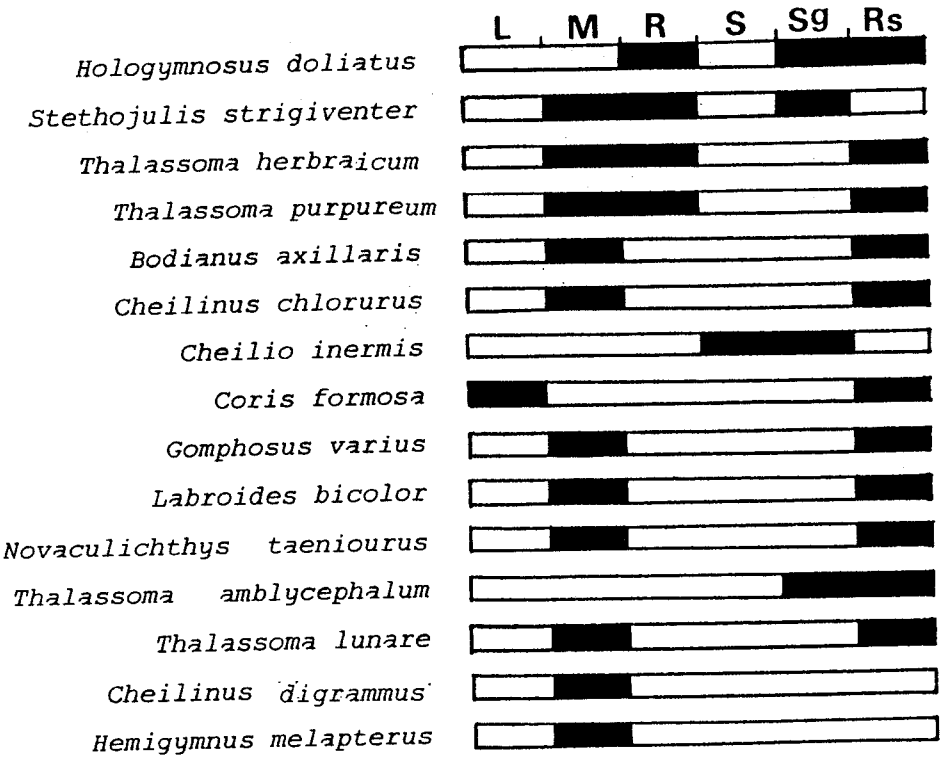
L
M
R
S
Sg
Rs
Hologymnosus doliatus
Stethojulis strigiventer
Thalassoma herbraicum
Thalassoma purpureum
Bodianus axillaris
Cheilinus chlorurus
Cheilio inermis
Coris formosa
Gomphosus varius
Labroides bicolor
Novaculichthys taeniourus
Thalassoma amblycephalum
Thalassoma lunare
Cheilinus digrammus
Hemigymnus melapterus
LUTJANIDAE
Gnathodentex aureolineatus
Monotaxis grandoculis
MALACANTHIDAE
Malacanthus latovittatus
MONOCANTHIDAE
Alutera scripta
Cantherinus pardalis
MUGILIDAE
Crenemugil crenilabis
MUGILOIDIDAE
Parapercis hexophthalma
MULLIDAE
Mulloides flavolineatus
Parupeneus barberinus

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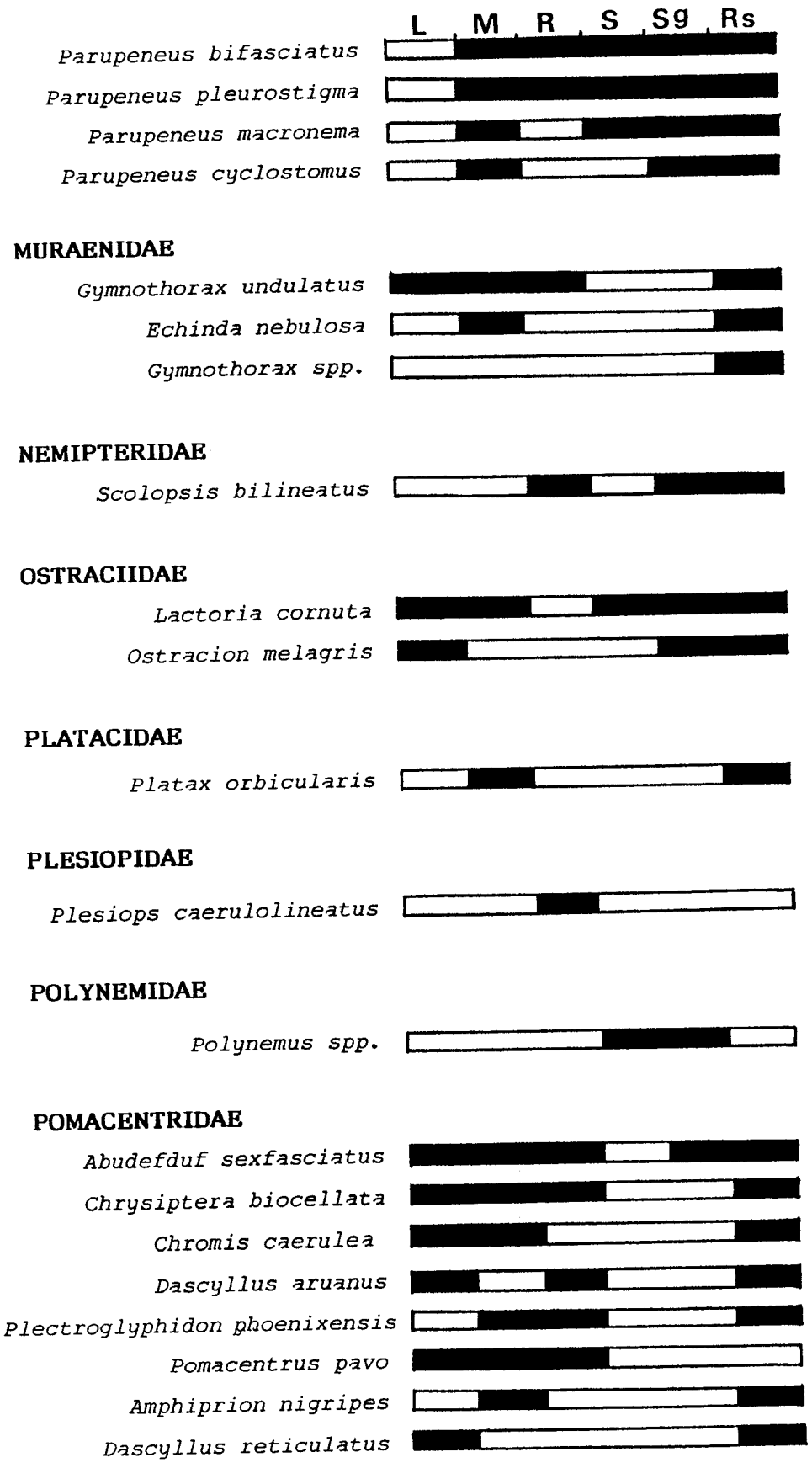
L
M
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Rs
Parupeneus bifasciatus
Parupeneus pleurostigma
Parupeneus macronema
Parupeneus cyclostomus
MURAENIDAE
Gymnothorax undulatus
Echinda nebulosa
Gymnothorax spp.
NEMIPTERIDAE
Scolopsis bilineatus
OSTRACIIDAE
Lactoria cornuta
Ostracion melagris
PLATACIDAE
Platax orbicularis
PLESIOPIDAE
Plesiops caerulolineatus
POLYNEMIDAE
Polynemus spp.
POMACENTRIDAE
Abudefduf sexfasciatus
Chrysiptera biocellata
Chromis caerulea
Dascyllus aruanus
Plectroglyphidon phoenixensis
Pomacentrus pavo
Amphiprion nigripes
Dascyllus reticulatus

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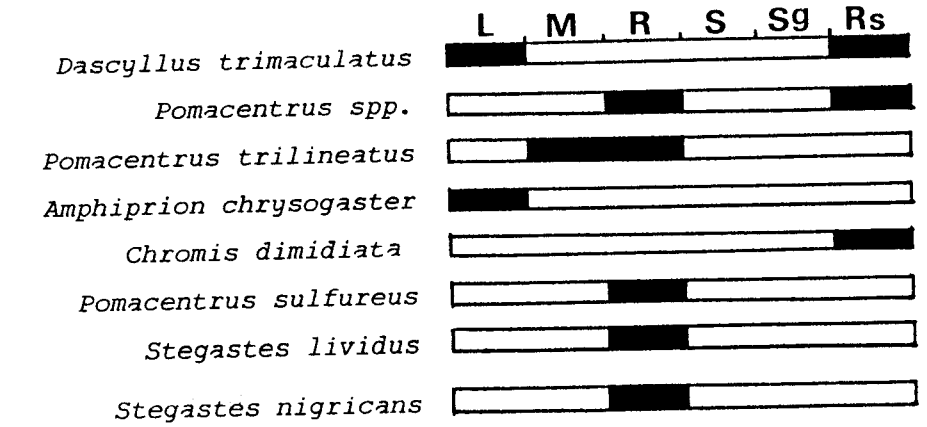
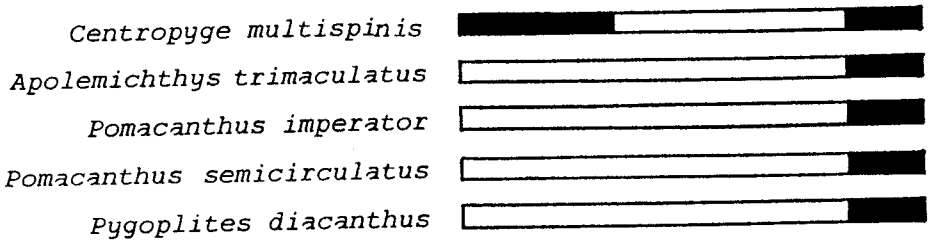
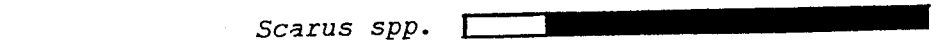


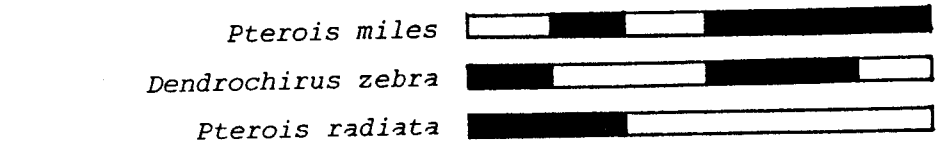
POMACANTHIDAE



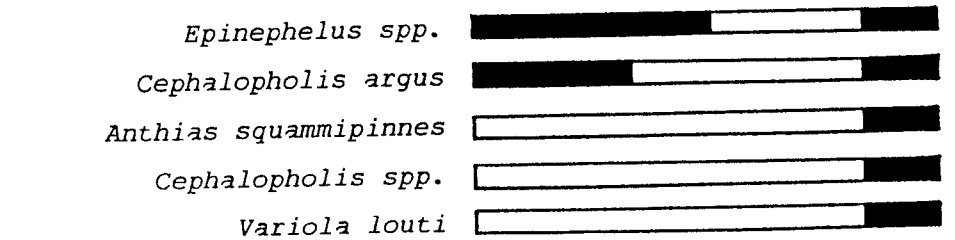
SCARIDAE



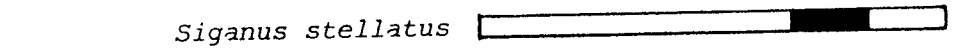
SCORPAENIDAE



SERRANIDAE



SIGANIDAE



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SPHYRAENIDAE

Sphyraena spp.

TETRAODONTIDAE

Tetraodon nigropunctatus

Canthigaster margaritata

Canthigaster valentini

THERAPONIDAE

Therapon jarbua

ZANCLIDAE

Zanclus canescens

only on massive coral and seagrass beds. C. solandri represented only the reef slope. Zanclus canescens was found in all regions except rubble and sand.

5. Community diversity

Diversity values obtained for each sub-habitat and the reef slope are given in Table 15. With regard to species on sub-habitats, highest diversity was recorded by massive coral (3.93) followed by rubble (3.58). Species diversity of live coral (3.16) and seagrass beds (3.14) were comparable while sand flats recorded 3.25. The reef slope recorded a high diversity of 4.45 (Fig. 13).

A total of 121 species were observed on the reef slope. Massive coral recorded 89 species followed by 65 species on seagrass beds. Rubble and live coral recorded 46 and 39 species respectively. Lowest number of species (28) were recorded on sand flats (Fig. 21).

DISCUSSION

The ways in which many reef fish species inhabiting a particular sub-habitat are organised into communities, their patterns and changes through time and in space are discussed in the following account. The species making up the assemblages may be expected to exhibit a wide range of food and micro-habitat requirements but groups of species with similar preferences are likely to be included (Sale 1980). Positive or negative behavioural interactions with one another due to trophic,

competitive or mutualistic relationships result in the formation of assemblages of a definable, interspecific social structure (Sale, 1980).

Community Parameters of species on sub-habitats and reef slope.

Live coral: Species richness of three families, namely Chaetodontidae, Labridae, and Pomacentridae was high and comparable, each of them consisting 7 to 8 species. Chaetodontids are known to spend their entire lives associated with a relatively small portion of the reef environment (Goldman and Talbot, 1976) while some species were relatively restricted in their distribution among zones and others widely distributed (Bouchon-Navaro, 1980, 1981, 1986; Fowler, 1990). Certain species (e.g., Chaetodon trifasciatus and C. trifascialis) are considered as obligatory coral feeders (Reese, 1981; Harmelin-Vivien and Bouchon-Navaro, 1983; Harmelin-Vivien, 1989; Sano, 1989) while certain species are considered as facultative coral feeders (Harmelin-Vivien, 1989; Sano 1989). In the present study, both C. trifascialis and C. trifasciatus were found among Acropora formosa patch reefs but low H' values (3.20 and 2.27) suggested that they were not as frequent as C. auriga that was most abundant. C. vagabundus is also known to feed on corals (Sano, 1989). Sutton (1985) observed that C. trifasciatus had larger territories within lagoon habitats and interpreted this as a response to low population density and poor habitat quality. As patch reefs are not very extensive on Kavaratti atoll, it is likely that obligate coral feeders are found in habitats with richer coral cover than on sparse coral patches. Bouchon-Navaro et al. (1985) found chaetodontid populations to decrease with degraded coral environment.

Due to the facultative feeding habit C. auriga (Hourigan, 1989) it is more flexible in habitat choice, and thus the abundance. C. citrinellus is a non-coral feeder (Galzin, 1987 b) while C. melannotus is a soft coral feeder (Adrim and Hutomo, 1989) and C. falcula was found to feed predominantly on polychate tentacles (Chapter IV). Low distribution of these species in the present study is probably due to varying habits mentioned above.

Among the seven labrids, Halichoeres scapularis was distinct from other species (H' = 4.21) in abundance and occurrence. Though this species did not seem to depend on this zone directly, it probably made use of interstitial sand patches for food procurement. This species was observed to be extensively associated with sand flats (Randall, 1983). Thalassoma hardwicki was observed on quiet reefs (Hiatt and Strasburg, 1960) while Coris gaimard was numerous where the reef was interspread with patches of sand (Hobson, 1974). In the present study, ramose corals perhaps did not suit T. hardwicki due to lack of shelter while the presence of C. gaimard supports the observation of Hobson (1974). It is also likely that C. formosa also follows the same pattern as these species feed on benthic invertebrates on sand. However, rare occurrences of these species on live coral suggest that their preferred habitats lie elsewhere on the reef.

Of the eight pomacentrids, only Dascyllus aruanus and Chromis caerulea occurred frequently in high numbers. The fact is substantiated by H' values (4.46 and 4.40 respectively) that weighted their occurrence in most censuses conducted. Relatively common species were D. trimaculatus

and D. reticulatus. Shpigel (1982) observed that D. aruanus and D. marginatus are coral dwelling species and occur together frequently. Reese (1978) stated that mobility of planktivores is constrained for want of shelter or nesting sites. Due to intense site attachement these species would have been included in most censuses. Pillai et al. (1986) reported coexistence of D. aruanus and Chromis caerulea on coral patches in Minicoy. Apart from this, few more interspecific associations, involving D. trimaculatus, D. reticulatus and Amphiprion chrysogaster were observed in the present study. The occurrence of A. chrysogaster was determined by the presence of small amemones on dead bases of Acropora formosa. Other rare species were accidental in occurrence.

The occurrence of Epinephelus spp. (probably E. hexagonatus) and Dendrochirus zebra and occassionally Gymnothorax undulatus is influenced by the readily available prey in the form of small pomacentrids and other invertebrates. E. hexagonatus were found to inhabit staghorn coral zones on Tutia reef (Talbot, 1965). The abundance and consistent occurrence of Centropyge multispinis is due to strong site attachment (as in pomacentrids) and were covered in most censuses. Ostracion cubicus was observed to be a weak swimmer, found around coral heads while (Tetraodon) Arothron nigropunctatus fed on corals (Hiatt and Strasburg, 1960). In the present study, occurrence of O. melegris and Tetraodon nigropunctatus could be possibly structured due to these habitats. A similar reasoning holds good for Balistoides viridescens. Though Paracirrhites forsteri is known to be associated with coral heads (Talbot, 1965; Galzin, 1987 b), they seem to

prefer the tabuloid Acropora humilis head over A. formosa . Other species that occurred only once could be considered as accidental.

Massive coral: Species richness of Labridae, Chaetodontidae, Acanthuridae, Pomacentridae and Mullidae was remarkably high, possibly due to the proximity of this zone to the reef front/reef slope and inherent topographic complexity.

Halichoeres centiquadrus was observed around coral mounds (Hiatt and Strasburg, 1960). Its dominance (H' = 4.27) over H. scapularis (H' = 4.04) suggests that massive coral zones are most preferred. Unlike other labrids, Labroides dimidiatus were numerically significant owing to their site attachement to suit its mutualistic behaviour as 'Cleaning symbionts'. In contrast L. bicolor moves over larger areas (Smith and Heemstra, 1986) and were possibly not included in censuses. Thalassoma hardwicki was found to inhabit calm reefs (Hiatt and Strasburg, 1960) and such conditions prevailed between massive coral heads. Chelinus trilobatus, C. digrammus and C. undulatus were found on the inner reef flats as sub-adults while adults were found on the outer reef slopes (Vivien, 1973). In the present study, adults were also found on massive coral zones perhaps due to their proximity to the reef slope. Hiatt and Strasburg (1960) reported the occurrence of Novaculichthys taeniourus on rubble and never around live coral while Gomphosus varius was common around lagoonal reefs. N. taeniourus in this case was found to shelter beneath massive coral patches. G. varius was more common than G. coeruleus. Occurrence of Coris gaimard and Stethojulis strigiventer could be correlated to the presence of interstitial sand patches, from where they pick up invertebrates.

According to the reports of Hobson (1974) and Harmelin - Vivien (1977), it appears that labrids belonging to genus Bodianus (Bodianus bilunulatus) occurr in depths more than 15 m. In the present study, B. axillaris appears to have migrated onto shallow regions; the reasons for which remain unclear. Other species were rare or occassional.

Chaetodon auriga typically dominated all chaetodontids (H' = 4.47) while C. citrinellus which is known to be a non-coral feeder (Galzin, 1987 b) was relatively dominant on massive coral zones. The frequent occurrence of these two species is also supported by the observations of Hiatt and Straburg (1960) and Grovhoug and Talbot (1976). This pattern could result due to their generalised diet but not as specific coral feeders like C. trifasciatus that occassionally occurred. Talbot (1965) reported C. falcula, C. melannotus and C. xanthocephalus to be coral feeders. C. lunula is partly nocturnal (Findley and Findley, 1989) and are non-coralline invertebrate feeders (Sano, 1989). C. kleinii is found on reefs with sandy coral bottom with little surge (Adrim and Hutomo, 1989). Heniochus acuminatus was reported from relatively deeper waters (Harmelin-Vivien, 1977). In the present study, rare occurrences of these species could be due to lack of abundant scleractinian corals on the massive coral zone. Species with nocturnal habits were probably not covered in censuses. Occurrence of C. kleinii could be due to the presence of interstitial sand patches, while H. acuminatus would have temporarily migrated onto massive coral zones.

Of all acanthurid species, dominance of Acanthurus leucosternon is known to have a greater feeding flexibility than A. lineatus and is restricted to a poor quality habitat (Robertson et al. 1979). Distributional difference of these species could be due to the reasons mentioned. Further A. lineatus was found on the surge zone (Harmelin-Vivien, 1977) and on the upper layer of the outer slope (Hiatt and Strasburg, 1960). This clearly indicates that the preferred habitat is not massive coral zone but is the adjacent reef slope. Therefore, the species was encountered only 3 times. Lower counts of A. triostegus was due to presence of other preferred sub-habitats in proximity while Acanthurus spp. (possibly A. dussumieri or A. mata) are species prefering the reef slope. Galzin (1987 a) observed A. triostegus to inhabit all lagoonal habitats. Choat (1991) stated that younger stages of the planktivorous members of the genus Naso commence life as hervivores and feed in open water as adults. It is perhaps due to this feeding ontogeny, that the three species of Naso were found in shallow massive coral zones. Harmelin - Vivien (1977) reported individuals of Naso and Zebrasoma from depths of 15-18 m. Numerical dominance of Scarus spp. could be due to the schooling nature of sub-adults and dubbing of species under one genus owing to practical problems in underwater identification. Abudefduf saxatilis schooled on patch reefs and reef tops but also moved individually in coral caves (Emery, 1973). A. sexfasciatus, in the present study exhibited the same behaviour and was consistently associated with massive coral zones ($H' = 2.52$). From the numerical data and H' values it was evident that other pomacentrid species were not typical of the region. The main cause could be shelter limitations for smaller pomacentrids.

Most mullid species are associated with sandy bottoms where they feed on invertebrates (Randall, 1968; Hobson, 1974) and differ in having a nocturnal or diurnal activity, but Parupeneus bifasciatus was found to be active at all times. (Hobson, 1974). P. barberinus was observed on sand/rubble zones (Grovhoug and Talbot, 1976). In the present study, occurrence of all send-dwelling species is correlated with interstitial sand patches present among the massive coral zone. Apart from the two dominant species, P. barberinus and P. macronema, others seemed to prefer more extensive sandy areas for foraging. Though less frequent, the presence of Parapericis hexaphthalma is also related to sand patches, on which it depends for shelter and food procurement.

Rhinecanthus aculeatus preferred sand or rubble zones near coral mounds (Hiatt and Strasburg, 1960) while they were found on lagoonal patch reefs (Grovhoug and Talbot, 1976). Rubble and sand zones were in close proximity on Kavaratti atoll thus determining the distribution. R. rectangulus on the other hand did not forage and was observed near the surf zone (= reef flat/reef crest) and ramose corals. At Lakshadweep, this species was rare and its counts were perhaps influenced by its varying habits. Melichthys niger and M. ringens fed on plankton in the water column (Hobson, 1974). They occurred in deeper waters on the reef slope on Kavaratti but some individuals would have migrated onto massive coral zones. Sufflamen bursa was reported to be wide spread in Hawaii and feed on benthic animals close to corals. This species was rare in Lakshadweep.

Paracirrhites forsteri is normally associated with coral heads (Talbot, 1965) and their presence on the massive coral zone was due to small colonies of Acropora humilis on which they rest to prey on fish. Cirrhites pinnulatus was reported to be a nocturnal predator and is in partial cover during day (Hobson, 1974) and due to nocturnal habits, they may not have been covered in the censuses. A similar explanation holds good for haemulids, holocentrids, muraenids and Grammistes sexlineatus. Hiatt and Strasburg (1960) observed Monotaxis grandoculis around coral mounds and Gnathodentex aureolineatus among deep lagoonal reefs; their observations were in accordance with patterns observed in the present study. Higher counts of G. aureolineatus was due to schooling nature. Predatory fishes like Epinephelus spp. (E. hexagonatus was most common), Cephalopholis argus, Pterois miles and P. radiata were common and perhaps more numerous but their cryptic nature would not have yielded a correct picture. Other species recorded on massive coral were occassional or rare.

Rubble: Labridae and Pomacentridae were the most species rich families, indicating that they can make use of rubble zones effeciently. Among labrids, only Halichoeres scapularis represented the zone in good numbers and regularly (H' = 4.45) while H' values below 2.50 for other species indicated sporadic occurrence. Its occurrence on rubble was also recorded by Randall (1983). As discussed earlier, adults of certain species (Cheilinus trilobatus and C. undulatus) that usually occur in deeper waters may be temporary visitors on the zone. C. trilobatus and Halichoeres centiquadrus were considered as generalists (Galzin, 1987 a) but such a

distributional pattern was not observed in the present study probably due to differences in ecological factors from varying geographic regions. Species of Stethojulis, S. albovittata and S. strigiventer were occassionally recorded on rubble - as they prefer small invertebrates for food. Thalassoma purpureum (commonly called the surge wrasse) was observed on the edge of the reef flat where turbulence is high (Sheppard et al., 1992) and its occurrence on the rubble zone could be due to proximity of the two regions. A similar reasoning also holds good for Hologymnosus doliatus and T. herbraicum.

Next in abundance were promacentrids where four species were recorded consistently (H' = 4.09 to 4.38). All species were characteristically site-attached but varied in relative abundance. Horn (1989) stated that these species were conspicuous and were frequent pugnacious residents of shallow water reef habitats having an omnivorous/ herbivorous feeding habit. The most speciose genera of omnivores were Pomacentrus and Chrysiptera while herbivores were Plectroglyphidodon and Stegastes (Choat, 1991). Damselfish derive shelter sites, nesting sites and food from their habitats (Robertson et al., 1981; Robertson, 1984). Rubble zones suited the habitats of these species and therefore determined their distribution on Kavaratti atoll. Some pomacentrids occurred accidentally, for example Dascyllus aruanus is normally associated with ramose coral but was found on rubble while Abudefduf sexlineatus normally inhabits high patch reefs at Kavaratti. Their presence on non-conventional habitats (rubble) could be due to chance colonization and not of systematic partitioning of living space (Sale and Dybdahl, 1975). Due to the cryptic

nature of these species, a certain element of bias during censuses could also alter the relative importance. Nevertheless, well spread out censuses over a period of time are likely to indicate somewhat realistic picture. Constraints in sampling were also applicable to gobiids, apogonids, Epinephelus spp., Plesiops caeruleolineatus and Gymnothorax undulatus due to their hiding behaviour or in certain cases a nocturnal behaviour, but were found to be abundant otherwise. Randall (1983) found Scolopsis bilineatus common along the reef edge and seemed to prefer deeper waters and its presence on rubble zones at Kavaratti could be explained due to proximity of the two regions. Parupeneus barberinus was weighed significantly through all censuses (H' = 3.19); and it was found on rubble/sand by Grovhoug and Talbot (1976) and Randall (1983). According to Hobson (1974), certain species are nocturnal and this could affect censuses. P. bifasciatus, P. pleurostigma and Mulloides flavolineatus seem to prefer sandy regions and hence their low counts on rubble.

Among balistids, Rhinecanthus aculeatus occurred in most samples (H' = 4.18) and perhaps depended on rubble for food and nesting sites. It had been reported from similar zones by Hiatt and Strasburg (1960) and Grovhoug and Talbot (1976). Melichthys indicus is non-typical of this zone but inhabits the adjacent reef slope. R. rectangulus shares similar preference to that of R. aculeatus but does not forage far from nearby coral shelter and surge zone. (Hiatt and Strasburg, 1960) and thus the low counts on rubble. Chaetodon citrinellus is a non-coral feeder (Galzin, 1987 b) while C. auriga feeds on polychaete tentacles or filamentous algae (Vijay Anand 1990a). Their presence on rubble could be explained owing to a

flexible feeding habit. Further, the absence of chaetodontids on this featureless habitat supports observations of Reese (1981), Harmelin-Vivien and Bouchon - Navaro (1983) and Adrim and Hutomo (1989) where chaetodontid species richness was observed to increase with coral cover.

Only Acanthurus triostegus formed the bulk among acanthurids (H' = 3.68) and most of them were sub-adults found in small schools. According to Hiatt and Strasburg (1960), A. triostegus feeds on filamentous algae and this was observed to be abundant on shallow rubble zones. Therefore food strongly determined the distribution of this species. Other species recorded were only occassional or rare and reasons regarding their distribution were discussed earlier (massive coral).

Sand flats: Though the family Mullidae was speciose, H' values never exceeded 3.92 indicating that they were relatively sporadic owing to their wide foraging behaviour and lesser chances of being included in the censuses. Parupeneus barberinus and P. macronema emerged consistent and they perhaps do not exhibit a pronounced nocturnal habit while it may be prevalent in other species. Hobson (1974) observed certain species of the genus Mulloidichthys (= Mulloides) to be nocturnal. Other species that depended directly on sand for shelter and associated organisms for food are Parapercis hexophthalma and Bothus pantherinus. Practical problems involved in censusing these species are that the former retracts into burrows in the presence of a swimmer (investigator) while the latter remains concealed under sand.

The only two species that seemed to use sand flats consistently are Acanthurus triostegus (H' = 4.06) and Halichoeres scapularis (H' = 4.43). The former fed on filamentous algae (Hiatt and Strasburg, 1960) that grew on sparsely strewn rubble while the latter fed on sand associated invertebrates. Importance of shallow waters for reef fish recruits is well known in A. triostegus (Sale, 1969) and the possible reasons for this could be favourable hydrological conditions, food resources and avoidance of predators. A similar reasoning holds good for sub-adult scarids that were numerically dominant. Randall (1983) found H. scapularis associated with sand flats.

Crenemugil crenilabis and Gnathodentex aureolineatus depended on sand flats for food organisms. As they are free swimmers they posed problems during censuses. Jones (1968) found C. crenilabis to feed on detritus and blue-green algae while Grovhoug and Talbot (1976) confirmed their association with sand flats. G. aureolineatus normally inhabited deep lagoonal reefs (Hiatt and Strasburg, 1960) but their presence on sand flats could have resulted from migrations from adjascent habitats for food. As sand flats on Kavaratti atoll were close to seagrass beds, species from both habitats are likely to affect counts. This situation is more pronounced with relatively free swimming individuals like Kuhlia mugil, C. crenilabis, Therapon jarbua, polynemids and sphyraenids. Hiatt and Strasburg (1960) reported polynemids from sand flats while Bardach (1958) stated that sphyraenids move over large areas. Their distribution over the reef therefore becomes spatially very uneven compared to the greater bulk of smaller species and rapidly changes with time (Talbot 1965).

Seagrass beds: Labridae, Chaetodontidae, Acanthuridae and Mullidae were the most speciose families on seagrass beds. Among labrids, though Halichoeres scapularis showed lower H' value (3.75) it was numerically dominant. The cover that seagrass canopy provides conceals many species and perhaps influenced counts. Its association with seagrass beds was recorded by Randall (1983). Stethojulis albovittata and S. strigiventer replaced other species on the list. With H' of 3.85 and 3.49 respectively, they indicated strong preference towards seagrass beds. Cheilio inermis occurred on sand flats but its main preference was seagrass beds. These species mentioned above emerged as typical dependents on seagrass beds. Hobson (1974) observed Coris gaimard to be abundant where the reef was interspread with sand patches from where they excavate burried organisms. Similar conditions offered by seagrass beds could determine its presence on the habitat. A similar explanation holds good for Hologymnosus doliatus. Other species were rare, but occur on the habitat for food and shelter. Most labrids, observed were sub-adults. Larger individuals of labrids and other benthic feeding fishes avoid areas of increased algal cover (Choat and Ayling, 1987).

Chaetodon auriga dominated seagrass beds (H = 3.94). All other species were occassional or rare. All individuals observed were juveniles except adult Heniochus acuminatus which were associated with cement pilings of the jetty. Chaetodon kleinii is found on reefs with sandy coral bottom and feeds on plankton while C. melannotus was more abundant at places with soft coral cover (Anderson et al., 1981). C. kleinii could obtain plankton from seagrass beds while it appeared that juvenile C.

melannotus were either omnivores or herbivores. Ontogenic feeding behaviour change was observed in C. auriga (Vijay Anand, 1990 a). Most juvenile chaetodontids perhaps had this habit, hence their association with grass beds. Clarke (1977) and Bouchon-Navaro (1981) observed juvenile/ subadult chaetodontids on grass beds.

H' values indicate that Acanthurus spp. and A. triostegus were consistent in occurrence. Most acanthurids were again juveniles or sub-adults in small schools except Zebrasoma veliferum and A. leucosternon that were non-schooling. Harmelin-Vivien (1989) and Horn (1989) observed juvenile acanthurids concentrated in shallow waters. Naso unicornis and N. tuberosus fed on larger algal species (Choat, 1991). In the present study, N. unicornis and N. brevirostris perhaps inhabited grass beds for macroscopic algae as food. Acanthurids were observed to have more species and individuals on reef crests and in lagoons (Russ, 1984 b) but species richness on seagrass beds was not significant. Apart from scarids that formed almost 50% of fish recorded, siganids are also expected to be dominant herbivores. However, only a single species, Siganus stellatus was recorded once. It appears that occurrence of siganids is highly seasonal as sudden summer peaks in recruitment were observed.

Many apogonids and holocentrids were collected during night time fishing (Chapter VI) and these species probably remain concealed during day time. A similar reasoning holds good for Bothus pantherinus and Parapercis hexophthalma but these species were diurnally active. Certain balistid species were observed to feed on seagrasses (Randall, 1965; Ogden and Zieman, 1977). The association of Balistoides viridescens,

Pseudobalistes flavimarginatus and Rhinecanthus aculeatus with sand patches was recorded by Hiatt and Strasburg (1960). In the present study, the occurrence of these species on seagrass beds could be related to the presence of interstitial sand patches and abundant invertebrate food. Other species visiting grass beds for prey procurement from sand were Monotaxis grandoculis, Malacanthus latovittatus, Crenemugil crenilabis and Scolopsis bilineatus. Bell and Pollard (1989) stated that Monacanthidae and Scropaenidae were among dominant families on seagrass beds, while Bell et al. (1978) observed monacanthids to be omnivores that act as herbivores and consume encrusted fauna and flora on seagrass blades. Monacanthids in the present study did not form a dominant group but dependence for food may be in accordance in case of Alutera scripta which was the only dominant species. Scorpaenids perhaps depended on the region for food in the form of abundant invertebrates and juvenile fishes (Harmelin-Vivien and Bouchon, 1976) while other species were rare. Harmelin - Vivien and Bouchon (1976) commonly observed fistulariids on seagrass beds; Fistularia petimba was observed as a typical seagrass bed resident in the present investigation. Observations in the present study were in accordance with those of Bell and Pollard (1989) who summarised major characteristics of seagrass beds as nurseries for reef fish, shelter and abundant food source. Several species make use of this zone as juveniles but occur as adults on nearby reefs Ogden and Zieman 1977; Weinstein and Heck, 1979; Shulman, 1985b). Free moving species belonging to Belonidae, Kuhlidae, Mugilidae, Polynemidae and Sphyraenidae posed problems in censusing but were characteristically of sand flats and seagrass beds.

Reef slope: Labridae, Chaetodontidae, Balistidae, Pomacentridae, and Acanthuridae were the most speciose families.

Among the labrids, five species, distinctly outweighed others (H' above 3.00). Halichoeres scapularis, H. centiquadrus and Thalassoma hardwicki were numerically dominant and this could be due to non-specificity of ecological niches required by them. Galzin (1987 a) found T. hardwicki to inhabit all lagoonal habitats while H. centiquadrus was included in his list of 'generalist species'. T. lunare was abundant and widely distributed on Heron Reef and found in all habitats with good shelter component (Robertson and Choat, 1974). In the present study, their consistent occurrence could be accounted by sufficient topagraphic complexity that the reef slope offered. Several hundreds of individuals of T. hardwicki and T. lunare are known to aggregate for spawning (Robertson and Choat, 1974) and perhaps such aggregations also contributed to species counts. Among the genus Cheilinus, C. undulatus was common. Vivien (1973) observed the adults of C. digrammus, C. trilobatus and C. undulatus on the outer reef slopes and perhaps had a lower representation on the sub-habitats. In the present study the rare occurrence of Bodianus axillaris could be related to their preference to greater depth regime and absence of relatively shallow reef slopes. A different species of the same genus (B. bilunulatus) occurred in depths greater than 15 m (Hobson, 1974) and between 35 to 50 m (Harmelin-Vivien, 1977). A variety of other species inhabited the reef slope as larger adults that required greater depths and foraging area. Labrids preferentially feed on benthic invertebrates (Chapter IV) and such fauna is known to be abundant where

the habitat provides sufficient protective cover (Parrish, 1987). The reef slope in this case has sufficient complexity and perhaps hoards abundant food resources.

H' values have separated Chaetodon auriga (H' = 3.78) and C. collare (H' - 3.52) as species that were regularly encountered on the reef slope. A comparable H' value of 3.02 in Forcipiger spp. could have resulted due to dubbing of two species that were found to coexist on the reef slope of Kavaratti atoll (Forcipiger longirostris and F. flavissimus; Chapter II, new records). Low occurrence of the obligate coral feeders, Chaetodon trifasciatus, C. trifascialis, C. vagabundus and C. triangulum could be related to over all paucity of rich coral cover on the reef slope, while in contrast, facultative/non-coralline feeders dominated the zone, including C. citrinellus. Talbot (1965) also grouped C. falcula C. melannotus. C. meyeri and C. xanthocephalus as coral feeders. The distribution and abundance of coral feeders is known to provide clues on the condition of the reef (Anderson et al., 1981; Reese, 1981; Harmelin-Vivien and Bouchon-Navaro, 1983) in which case their abundance and occurrence was low (1 to 7 times out of 22 censuses) perhaps due to a relatively unhealthy reef condition owing to various human activities, especially dredging and blasting of the reef.

Greatest number of balistid species were found on the reef-slope as compared to other-sub-habitats. Two important factors that probably determined this pattern was the behaviour of certain balistids which required deeper waters and topographic complexity of the reef slope. This is supported by a clear dominance of Melichthys indicus (H' = 4.52)

and Odonus niger (H' = 3.34) and to an extent by Balistapus undulatus, Balistoides conspiculum, Balistes ringens, Sufflamen bursa and S. fraenatus which seemed to prefer relatively greater depths. This could be substantiated by the observations of Hobson (1974) who observed Melichthys niger and M. ringens to feed on plankton in the water column. Harmelin-Vivien (1977) in her study on the fish community of the reef slope of Tulear reef, found Balistapus undulatus, Sufflamen bursa and S. chrysoptera between depths of 18 and 25 m.

The pomacentrid community was generally dominated by planktivores in contrast to that observed on rubble zones with omnivores/herbivores. Diurnal planktivores concentrate along the reef edge and feed mainly on transient zooplankters from open waters (Reese, 1978; Hobson, 1991) and aggregating planktivores belong to the genera Chromis and Dascyllus (Choat, 1991). In the present study, numerical dominance of Chromis caerulea, Dascyllus aruanus and D. reticulatus could be related to the reasons mentioned. Counting these small site attached species posed problems due to distance of observation and aggregating behaviour. The dominance of Chrysiptera biocellata could be explained by their ominivorous feeding habit which permits non-localized distribution. Feeding adults of Abudefduf saxatilis occurred on reef tops with little surge (Emery, 1973) and similar colonization patterns were observed in A. sexfasciatus in the present study.

Acanthurus spp. (H' = 4.00) dominated the reef slope scenario. The species is possibly A. dussumeri but due to similarly occurring species such as A. mata, it was considered only upto generic level.

Conspicious dominance of three other species (A. leucosternon, A. lineatus and Naso unicornis) is perhaps related to the presence of desired algal food on the reef slope or the nearby reef flat. N. unicornis was reported to feed on algal turfs (Choat, 1991) and foliose algae (Hiatt and Strasburg, 1960). Most members of the genera Acanthurus and Zebrasoma feed over reef substrata and graze turf algae (Jones, 1968; Robertson and Polunin, 1981). Depth distribution of herbivores are ultimately constrained by their algal food supply which are light dependent organisms (Thresher and Colin, 1986) and therefore acanthurids predominate shallow habitats (Bouchon-Navaro and Harmelin-Vivien, 1981). Acanthurus lineatus is usually restricted to the flats and adjacent reef fronts (Choat, 1991) and its occurrence on the reef slopes is perhaps justified in the present study and probably feeds on the reef flats where algal food was observed to be abundant. Robertson et al. (1979) reported the coexistence of A. leucosternon and A. lineatus but are seggregated on the same habitat owing to morphological limitations related to food habits. In the present study, these species co-occurred but the former was more abudant; this could be due to a greater feeding flexibility observed in A. leucosternon (Robertson et al, 1979). Poor representation of A. triostegus implies its preference towards shallower lagoonal habitats. Zooplanktivory in certain species of the genus Naso was reported by Hobson (1974) and obviously the most preferred zone would be the reef front with open incoming currents. It is therefore possible that these species inhabited deeper waters than those found on the reef slope and were not included in the censuses. However, certain stray individuals of N. vlamingii and N. brevirostris were present.

As Paracirrhites forsteri was always found on Acropora humilis head, they perhaps are specific to the particular species of coral. Their greater representation could also be related to their preference of the surge zone (Hiatt and Strasburg, 1960). Plectorhinchus orientalis was represented regularly on the reef slope (H' = 3.03) but lower numerical status is due to solitary occurrence as compared to the schooling behaviour of P. gibbosus. However, Haemulidae had a poor representation in Lakshadweep. Parrish (1987) stated that these species were conspicious, loiter by day in exposed schools and form an important segment of reef fishes in the Western Atlantic but other families replace this group in Pacific and Indian Oceans. A variety of nocturnal species were perhaps not spotted or were underestimated in the present study. Such groups included apogonids, holocentrids, and muraenids, which were found to be otherwise abundant in fish catches at night. Similarly, schooling lutjanids and some lethrinids, as mentioned earlier were deleted to avoid overemphasis but these two groups were very dominant on all habitats, particularly on the reef slope. Gnathodentex aureolineatus seemed to prefer shallower habitats while Monotaxis grandoculis was solitary. Low numbers could be attributed to its nocturnal behaviour as observed by Hobson (1974). Hiatt and Strasburg (1960) observed G. aureolineatus among deep lagoonal reefs and surge zones and M. grandoculis around coral mounds.

Monacanthids had poor representation. Their presence could be due to certain species that fed on coral tips and coralline algae (Hiatt and Strasburg, 1960) A similar explanation also holds good for Tetraodon

nigropunctatus (Tetraodontidae). Normally, reef slopes harboured few sand associated communities like mullids and mugiloidids. Parupeneus barberinus and P. bifasciatus consistently occurred among patch sand pockets on protected were. Randall (1983) observed certain mullid species to inhabit reef sand areas and Hobson (1974) stated that they had wide foraging ranges. Hiatt and Strasburg (1960) recorded P. cyclostomus as solitary individuals. Considering observations of certain authours, it is evident that mullids prefer a homogeneous, uninterrupted foraging expanse which the reef slope does not offer. This could also determine their assemblages.

Pomacanthids in general were rare except Centropyge multispinis that was abundant on lagoonal patch reefs, other species seemed to prefer deeper waters. Randall and Hartman (1968) observed pomacanthids and chaetodontids to feed on sessile invertebrates like sponges and these were perhaps existing in good quantities on the reef slope. A similar reasoning holds good for Zanclus canescens. Hobson (1974) observed this to feed on sponges. Numerical dominance of Anthias squammipinnes is due to their schooling behaviour. Epinephelids were abundant where coral shelter was more (Talbot, 1965) while Variola louti and Cephalopholis argus were common on the reef slope (Harmelin-Vivien, 1977; Galzin, 1987 a) and the observations in the present study are in accordance with these findings. Possibly due to the occurrence of certain species of the genera Cephalopholis and Variola at greater depths (Randall and Brock, 1960), they were not encountered on the relatively shallow reef slope. A similar reason may hold good for scarids. Adult scarids were observed as solitary individuals on the reef slope in contrast to schooling sub-adults on

lagoonal habitats. Choat (1983) found that depth distribution in scarids interacted with features of reef structure. Bouchon-Navaro and Harmelin-Vivien (1981) observed scarids to predominate deeper waters while Galzin (1987 a) included Scarus sordidus in his list of 'generalists' on the reef slope. Due to preference of deeper waters and solitary behaviour only few scarids were recorded on the reef slope. Hiatt and Strasburg (1960) recorded Canthigaster valentini on shallow seaward reefs. In the present study, C. valentini was recorded only from the reef slope while C. margaritata was a generalist on all shetered areas. Apart from what was obtained through visual censuses, many other rare species were observed or fished during the course of study. This species richness undoubtedly makes the reef slope and the adjacent physiographic zones on the windward reef, the zones with greatest fish species diversity.

Though the family composition was constant (26-27 families) a marked variation in species richness on the reef slope, massive coral and seagrass beds was evident due to a greater diversity of species within each family. This could be directly correlated to the topographic complexity that can support various species which was greater on the reef slope. A greater complexity provides a greater diversity of shelter sites and surface area for algae and invertebrates (Luckhurst and Luckhurst, 1978 a). Similar observations were made by Carpenter et al. (1981), Ben - Tuvia et al. (1983), Bell and Galzin (1984) and Thresher and Colin (1986). The diversity on massive coral zone could be due to its proximity to the reef slope, while in the seagrass beds it is due to their role as nurseries and foraging grounds for many reef fishes. These facts were also

discussed by Harmelin-Vivien and Bouchon (1976), Ogden and Zieman (1977), Den Hartog (1979), Weinstein and Heck (1979), Shulman (1985a) and Bell and Pollard (1989). H' values (community diversity) supported the richness patterns exept in seagrass beds where an increase in species did not elevate H' values. This is due to the fact that species were not evenly distributed on seagrass beds as it supported transient individuals. H' values for live coral, rubble and sand were in accordance with richness patterns observed.

Seasonal variation in community parameters

Live coral: Though the number of species did not vary much during monsoon, variation in total individuals indicated that each species supported varying number of individuals and the least during peak monsoon. This is also supported by H' and J' values. As recruitment occurs during summer and the monsoon follows almost immediately in Lakshadweep, fish species count could possibly be influenced due to mortality or movements from affected areas. A similar reasoning was proposed by Jones (1991). A higher variation in community parameters during premonsoon could have resulted due to new recruits from the late post-monsoon months (November, December) coupled with effects of summer months. Summer peaks in recruitment were recorded by Sale and Dybdahl (1975) and Coles and Tarr (1990). As seen earlier, most fish populations among live coral are resident and variations could result mainly through factors affecting new recruits rather habitat shifts. Sale (1983) observed a highly variable community structure of fishes from one census to another on patch reefs

and suggested that a variable pattern of settlement of new juvenile fish plays a major role in determining fish assemblages. Other than random settlement, predation pressure also influences assemblages (Shpigel, 1982).

Massive Coral: As in the live coral zones, variation in species and total individuals was low, perhaps due to monsoon effects. A transient nature, lack of site attachement and ability to move from an unfavourable zone could have influenced fish assemblages. The proximity of the massive coral zone to the reef crest enhances the physical disturbance. A higher variation in H' and J' values indicates instability during the season. Fluctuations of individuals and species in pre-monsoon and post-monsoons is due to prevalence of calm conditions that allow the to and from movement of fishes from the adjacent species rich reef slope. Ogden and Quinn (1984) discussed about migration of fishes due to diel patterns in feeding or resting. A similar pattern in haemulids was recorded by Meyer et al. (1983). H' and J' values supported the observed pattern and a high variation during premonsoon resulted due to 447 individuals recorded in August.

Rubble: Compared to massive coral zones, rubble zones are shallow habitats and are close to the reef flat/reef slope. A low variation in the community parameters during monsoon is perhaps due to rough conditions. The very fact that it is storm cast rubble substantiates the fact. The unstable nature of this habitat strongly influenced seasonal fish assemblages. Lassig (1983) observed that a cyclonic storm caused high juvenile mortality and redistribution of sub-adult fishes while adult fishes

remained unaffected. Walsh (1983) pronounced local change in habitat features. In the present study, as most of the species observed were small territorial pomacentrids, physical disturbance to the habitat would certainly have altered their assemblage structure, which in turn varied the counts. The larger species capable of migrating would have shifted to the reef slope area. A higher variation in community parameters during pre-monsoon and post-monsoon could be due to recolonization of resident species and frequent visitors from the adjacent reef slope. Rubble harboured abundant turf algae which attracted schools of sub-adult herbivores resulting in variations.

Sand flats: A characteristic feature of sand flats is that it does not offer any shelter but can act as a food hoarder in the form of sand dwelling invertebrates. Thus, these zones were utilized by a relatively smaller proportion of reef fishes (evidenced by lower counts of individuals). Variation in community parameters was high in monsoon and pre-monsoon as compared to post-monsoon. As recognized stable patterns of fish assemblages were not detected, causative agents in structuring these communities cannot be reasoned out. However, some general processes occuring amongst reef fishes can explain the patterns partly. Except for a single census that yielded an unusual count of 135 individuals, enhanced by schooling scarids, variation between other censuses was low and comparable to other seasons. The pre-monsoon trend is perhaps due to ingress of individuals from the neighbouring seagrass beds. Fish were observed to leave seagrass beds and cross to nearby sandy areas perhaps temporarily for feeding . Feeding aggregations as seen in certain

sand associated species (Acanthurus triostegus, Halichoeres scapularis and a variety of mullids) could also determine the variation in numerical patterns.

Seagrass beds: In contrast to sand flats and other habitats, high counts and pronounced variations make seagrass beds unstable habitats. Pollard (1984) did not find significant seasonal differences and stated that high H' values are due to high species richness and evennes of distribution. But in the present study, monsoon assemblages were relatively stable perhaps due to lack of excessive new recruits and a habitat shift by most species. Lack of new recruits could result, through seasonal variations in spawning. Spawning activity has been selectively modified to match favourable oceanographic conditions for larval survival and dispersal (Johannes, 1978) and such a mechanism possibly explains low rates of settlement on to the 'seagrass nurseries'. Adult fishes, however, seem to avoid the area due to unfavourable conditions on the shallow habitat. Seagrass beds contain juveniles of several species that occur in the adult fauna of neighbouring reefs (Ogden and Zieman, 1977) while many species use seagrass beds for short or long durations (Den Hartog, 1979; Parrish, 1989; Bell and Pollard, 1989; Sheppard et al., 1992). Recruitment of temporary residents was found to be a principal cause of seasonal variation in fish abundance on seagrass beds (Middleton et al., 1984). A higher variation in other seasons (pre-monsoon and post-monsoon) could be explained by the reverse mechanisms where new recruits and fishes that use grass beds for the abundant food it stores, are brought in from other habitats.

Reef slope: This zone pictured a different trend with greatest seasonal variation during pre-monsoon. H' and J' values supported the patterns observed. As mentioned earlier, one reason could be due to new recuits while the other is perhaps due to certain spawning aggregations that might have been included in the censuses. Such aggregations were reported by Robertson and Choat (1974) and Warner (1982) for wrasses, Colin and Clavijo (1978) for goatfish, Colin (1978) for parrotfish, Colin (1982) for groupers and other reef fish in general. Counts could also be enhanced due to feeding aggregations (acanthurids, scarids) (Horn, 1989). Monsoon data cannot be interpreted due to incomplete sampling during rough sea conditions. H' for the few available samples was high indicating a stable nature. The shallowest parts of the reef comprise stressful environment in which to live (Sheppard et al., 1992) and this could be pronounced during monsoons (on shallow sub-habitats) in Lakshadweep resulting in a habitat shift for larger fishes. Walsh (1983) observed the shallow reef flat devoid of fish, while deeper areas had more fish due to habitat shift that substantially reduced immediate impact of storms. Relatively lower community parameters during post-monsoon could be attributed to a reverse process which involves fish migrations to shallow habitats primarily for feeding.

As seen in the earlier sections, distinct species assemblages were associated with different sets of habitats. Many physical and biological factors within a single subhabitat were discussed as possible determinants of community structure. Seasonal influences, particularly the regular monsoon effect, had pronounced effects on assemblages of fishes also during pre - and post-monsoon seasons. A highly variable pattern between each

census was observed, while the same data when pooled reflected seasonal variations. The patterns of variation may be consistent interannually as monsoon at Lakshadweep is an annual phenomenon.

Species distribution on sub-habitats: The abundance of Acanthurus triostegus was clearly distinct from the rest of the species. Its H' and J' values indicate that it occurred consistently and inhabited all sub-habitats in similar proportions. Such observations on this species were also made by Galzin (1987 a). Its presence could be related to its feeding habit on filamentous algae which was abundant on all hard substrata(e.g., rubble). This was followed by Acanthurus spp. (a complex, probably consisting of A. dussumieri or A. mata which were difficult to identify underwater) that characteristically occurred on habitats with hard surface. A. dussumeri was reported to be ubiquitous and though majority of them occurred in more than one location, maximum numbers were observed in one or two locations (Williams, 1982). Relating his observations, in the present study this species was dominant on seagrass beds. A. leucosternon and A. lineatus perhaps concetrated on the massive coral zone due to proximity of the reef slope where they were normally abundant. The former dominanted numerically and the reason could be due to certain observations made by Robertson et al. (1979) who stated that A. leueosternon had a greater feeding flexibility. Despite the schooling nature of A. lineatus their occurrence was low on lagoonal habitats. This could be explained by the observations of Choat and Bellwood (1985) where this species was restricted to reef crests and possessed a strong site attachement. Except Naso lituratus, other species of Naso and Zebrasoma generally inhabited

deeper waters of 15 to 18 m (Hobson, 1974, Harmelin-Vivien, 1977). Distributional patterns observed in the present study were in accordance with these observations, in the sense that massive coral zone which is close to the reef slope supported these species occassionally, while their occurrence on seagrass beds was mainly as sub-adults. Juvenile acanthurids were found to gather on shallow lagoon areas while adults of greater size were more numerous on the outer slope (Harmelin-Vivien, 1984). As depth preference on the neighbouring reef slope is 6-12 m in the case of N. lituratus (Harmelin-Vivien, 1977) it perhaps was at a vantage position to migrate on to shallower habitats.

Among all balistid species, Rhinecanthus aculeatus had the widest habitat distribution (H' = 1.21) but a J' value of 0.52 and abundance data suggested a preference towards rubble which could be due to the presence of preferred food items. Its occurrence on sand, rubble and lagoonal patch reefs as reported by Grovhoug and Talbot (1976) probably makes it a generalist. Balistoides viridescens was observed on sandy bottoms around live coral patches and free on live coral tips (Hiatt and Strasburg, 1960). In the present study, this behaviour explains their dominance on live coral. As discussed earlier (reef slope), other balistids seemed to prefer deeper habitats and therefore had a lower representation with occassional occurrences on neighbouring habitats (massive coral and rubble). Rhinecanthus rectangulus was recorded from the surf zones while Pseudobalistes flavimarginatus was found on sandy bottoms (Hiatt and Strasburg, 1960) nesting on the margins of channels (Lythgoe, 1971). In

the present study, P. flavimarginatus was found on seagrass beds and perhaps migrated from the adjacent sand flats.

An overall picture on chaetodontids indicated that most of them had specific habitat preferences on live coral, massive coral and seagrass zones. The relationship of chaetodontids with live coral has been discussed earlier. Their occurrence on massive coral zones could be related to the proximity of the reef slope zone which has a relatively higher live coral cover; while seagrass beds supported only juweniles and sub-adults. H' values indicate that Chaetodon auriga and C. citrinellus had the widest habitat range. C. auriga was commonly observed in pairs, travelling widely through sandy channels between coral heads (Findley and Findley, 1989) and was found to feed on polychaete tentacles and filamentous algae at Kavaratti (Vijay Anand, 1990a). C. citrinellus was reported to be a facultative coral feeder (Sano, 1989) while Galzin (1987 b) reported that it was found on all habitats and was a non-coral feeder. In the present study, it exhibited an omnivorous habit (Chapter IV). The observed patterns in these two species is possibly due to their adaptation towards a more flexible feeding behaviour. A similar reasoning explains habitat preferences of C. xanthocephalus and C. melannotus (supported by evidence on food habits; Chapter IV). C. xanthocephalus and C. melannotus were reported to feed on corals (Talbot, 1965) while the latter also fed on soft corals (Anderson et al., 1981). The obligate coral predators, C. falcula (Talbot, 1965), C. trifascialis, C. trifasciatus (Anderson et al 1981; Reese, 1981; Harmelin-Vivien and Bouchon Navaro, 1983). C. vagabundus (Sano, 1989) was found to be relatively rare. Occurrence of C. trifascialis and C. vagabundus was low perhaps due to the

absence of desired coral species for food and their strong site attachment to an extent indicates non-adaptability. In contrast, C. falcula and C. trifasciatus showed change in feeding habits (Chapter IV) and were perhaps more adaptable towards a deteriorating environment. Heniochus acuminatus was reported from a depth range of 18 to 25 m (Harmelin-Vivien 1977) while in the present study H. acuminatus was found on relatively shallow depths on the sub-habitats. The rare occurrence of H. monoceros could possibly be attributed to depth preferences. As Chaetodon lunula was considered a nocturnal species (Hobson, 1974) it was perhaps not covered during counts and was found sheltering among massive coral. A relatively high numerical abundance of C. collare was due to their aggregations in small groups. As C. kleinii fed mainly on plankton (Anderson et al., 1981; Chapter IV) it perhaps occurred in open waters. Its presence on the massive coral and seagrass beds could be related to abundant plankton. Kingsford (1989) suggested that hydrobiology may influence the composition and abundance of zooplankton which may in turn influence feeding of fish.

The strong preference of Acropora heads by Paracirrhites forsteri structured its distribution. Their representation was lower on the massive coral zone due to patchy distribution of ramose corals. Similar distribution was recorded by Talbot (1965) and Hobson (1974). Most of the massive coral dwellers are migrants from the adjacent reef slope. Hobson (1974) observed Cirrhites pinnulatus on surge zones and were nocturnal predators and hence their low counts in the present study. Hobson (1974) also stated day-time hiding habits and nocturnal activity of Diodon histrix.

Its dominance on seagrass beds in the present study could be related to their settlement as juveniles, which was recorded by Ogden and Zieman (1977). Despite nocturnal activity in soapfishes (Grammistidae) (Hobson, 1965) Grammistes sexlineatus was rarely spotted at Kavaratti. Its occurrence on live and massive coral zones indicate that structural complexity apart from food, determines their preference. Other nocturnally active species belonging to Apogonidae, Haemulidae, Holocentridae and Muraenidae characteristically dominated habitats that provided sufficient cover during day time (massive coral and seagrass beds). Meyer et al. (1983) stated that juvenile haemulids feed among seagrass beds at night and rest over coral heads by day.

As evidenced by H' values (2.23), Halichoeres scapularis indicated greatest habitat diversity and could be termed as a generalist. Randall (1983) reported its occurrence on rubble, sand and seagrass zones. In the present study, their dominance on the zones observed by Randall was in agreement but were also found on live and massive coral zones with a lower magnitude. In contrast, H. centiquadrus preferred massive coral zones perhaps due to varying food preferences or a relatively lower foraging range. This species was considered as a generalist by Galzin (1987 a). The two species of the genus Stethojulis, S. albovittata, S. strigiventer and Cheilio inermis indicated strong preferences towards seagrass beds. The species of Stethojulis were mainly observed on rubble and sand (Hiatt and Strasburg, 1960) but their dominance on seagrass beds is probably for food. Attachement to a particular site (territorality) and hostility towards conspecifics form the basis of a stable social system in the cleaner

wrasse, Labroides dimidiatus (Robertson and Choat, 1974). In the present study, its dominance on massive coral zone is perhaps due to two reasons; the site attachement and presence of regular, visiting host fishes to suit its 'cleaning behaviour'.

Juveniles of Cheilinus trilobatus, C. undulatus and C. digrammus were found on the inner reef flat while adults predominated outer reef slopes (Vivien, 1973). In the present study, the massive coral zone corresponds to the inner reef flat (within the lagoon) that follows the reef crest. Therefore, the dominance of these species, including C. chlorurus on the massive coral zone is justified. A majority of other labrid species dominated either the massive coral or the rubble zones and the pattern was perhaps due to the proximity of the reef slope from where fish migrate to and fro primarily for feeding. H' value (1.23) of Thalassoma hardwicki indicated wider habitat preference at Kavaratti. They were reported from all lagoonal habitats (Galzin, 1987 a). The abundance of Coris gaimard on reefs interspread with patches of sand from where burried invertebrates are excavated was recorded by Hobson (1974). Their occurrence on seagrass beds could be related to basal soft bottom sediment and their associated infauna and interstitial sand patches on other habitats. C. formosa was however rare. Thalassoma lunare was found among habitats with a good shelter component (Robertson and Choat, 1974) and such characteristics were offered only by massive coral zones. Hologymnosus doliatus, Anampses caeruleopunctatus and Thalassoma amblycephalum predominated seagrass beds for the abundant invertebrate fauna and small epiphytic gastropods as food.

According to Hiatt and Strasburg (1960), Gomphosus varius was found on ramose coral zones, Hemigymnus melapterus among coral heads, and Novaculichthys taeniourus on rubble zones. In the present study, these species were associated only with massive coral and were probably temporary visitors foraging away from their preferred habitats. Other species were rare and most of them were perhaps transient species migrating from the nearby reef slope. Species richness is highly correlated with substrate rugosity and a greater complexity provides a greater diversity of shelter sites and surface area for algae and invertebrates (Luckhurst and Luckhurst, 1978a). The characteristic association of labrids with massive coral and rubble zones could probably be explained by the influence of surface characteristics, while those associated with seagrass beds could arise from two categories namely, temporary adult visitors for food and juveniles/sub-adults resident in the habitat. Various fauna and flora of seagrass beds including fish have been described by Den Hartog (1979) while Bell and Pollard (1989) summarised the mechanisms mentioned.

Gnathodentex aureolineatus was observed among deep lagoonal reefs and surge zones and Monotaxis grandoculis among coral mounds. (Hiatt and Strasburg, 1960) but in the present study the occurrence of the former ws on relatively shallow massive coral zones while habitat preferences of the latter tallied with the present observations excepting that they were also recorded on seagrass beds. Hobson (1974) stated that M. grandoculis is a nocturnal predator. Malacanthus latovittatus occurred only twice and therefore its habitat preference cannot be determined. However, based on

underwater observations, it was evident that it moved about on a large area and preferred deeper waters. Monocanthids, Alutera scripta and Cantherinus pardalis clearly preferred seagrass, beds perhaps for food. Bell and Pollard (1989) indicated that Monocanthidae was one among the dominant families found on seagrass beds. While certain species were reported to consume seagrass (Randall, 1965; Ogden and Zieman, 1977) some species were omnivorous and fed on epiphytic fauna and algae on seagrass (Bell et al., 1978) and some fed on filamentous and coralline algae (Hobson, 1974). Crenemugil crenielabis was specifically found on sand, and as it is a benthic detrivore, it was associated with habitats composing soft sediments (sand and seagrass). Its association with sand flats (Grovhoug and Talbot, 1976) and as a detritus/blue green algal feeder was observed by Hobson (1974). As generalised detritivores, mugilids were found to be differentially associated with a variety of shallow habitats (Parrish, 1987). The site attached nature as an additional character with food procurement makes Parapercis hexophthalma to have a restricted distribution on sand.

All species of mullids exhibited a wide range of habitat preference (H' = 1.42) to 1.94) with Parupeneus barberinus and P. bifasciatus having the most consistent distribution. Individuals found on seagrass beds were mainly juveniles. Certain species of mullids were observed to inhabit sandy areas with juveniles on seagrass beds (Randall, 1968) all of which mainly fed on invertebrates in sand (Hobson, 1974). Hobson further stated that a portion of mullids were nocturnal. However, diurnal and nocturnal activity in P. bifasciatus was observed. Consistent occurrence of the two

tops and surge zones of 2.5 m deep. As already mentioned earlier, two distinct feeding patterns, namely the planktivores (Chromis and Dascyllus) and omnivores/herbivores (Chrysiptera, Plectroglyphidodon, Pomacentrus and Stegastes) exhibit different but specific habitat requirements. The former groups in the present study confined to live in ramose coral while species belonging to the second group were restricted to rubble zones, mainly to suit their feeding habits. An exception was seen in Amphiprion nigripes (associated with anemones on massive coral) and A. chrysogaster (associated with anemones at the dead bases of live coral) where their distribution is influenced by their symbiont. Occurrence of the only pomacanthid, Centropyge multispinis on live coral is related to its requirement of shelter and planktonic mode of feeding.

Greatest number of scarids occurred as juveniles on seagrass beds, and their roving herbivorous habit influenced their wide representation on all habitats except live coral. Hiatt and Strasburg (1960) reported that certain scarids fed on live coral and also described their occurrence among glomerate coral heads and surf zones. In the present study, scarids did not occur in these zones probably because only large individuals were found to feed on corals. Randall (1965) stated that herbivorous reef fishes have a circumscribed niche during day and scarids fed on seagrass and encrusted algae on dead corals. The patterns observed in the present study agreed with these observations.

Scorpaenids and serranids required ambuish sites on the reef to suit their predatory behaviour. This perhaps explains their habitat

choice. Scorpaenidae was among the dominant families listed from seagrass beds (Bell and Pollard, 1989) and the presence of Dendrochirus zebra and Pterois miles on sand flats could be due to the adjacent seagrass beds where they occurred. Epinephelus spp. (majority of them were E. hexagonatus) had a wider habitat range. This species was reported to inhabit shallow waters among lagoonal reefs or bays (Randall and Brock, 1960) and around coral shelter (Talbot, 1965). Talbot also observed epinephelids and Cephalopholis argus around massive corals. This was in accordance with present observations. In general, serranids yielded better to simple handling rather than visual census methods because of their cryptic habit. Preferences of siganids cannot be concluded due to rare occurrence but personal observations indicated that they are abundant seasonally on seagrass beds. Tetraodon nigropunctatus clearly indicated preference towards live coral and seagrass. This could be explained by observations of Randall (1974) who stated that tetraodontids feed on corals and Randall (1965), Ogden and Zieman (1977) observed feeding on seagrasses. Zanclus canescens fed on sponges (Hobson, 1974) and in the present study, these sessile invertebrates were perhaps abundant on massive coral zones. Juveniles of Z. canescens occurred on seagrass beds.

In comparing all zones including the reef slope (Fig. 26) most of the acanthurids, labrids and mullids were present on the reef slope and at least one sub-habitat, except Naso vlamingi that was recorded only from the reef slope. Balistidae, Chaetodontidae, Pomacanthidae and certain large serranids had significant number of species that were represented only on the reef slope. This pattern primarily reflects on specific depth

requirement in certain species independent of other resources like food or shelter. Some species that restrict themselves to the shallower sub-habitats are influenced by enhanced growth of algal food or limitations arising due to body structure and swimming capabilities, predation risks etc. The present study has therefore indicated a high variation in community structure of certain reef fishes on different spatial scales. Habitat selection in diurnal fish species sampled correlates highly with their requirements of preferred food and shelter. These resources in turn are determined by habitat complexity. It can therefore be concluded that a greater habitat complexity will support greater species richness of reef fish. Distribution of fishes among habitats have been variously related to topographic complexity (de Boer, 1978; Luckhurst and Luckhurst, 1978a, Bell and Galzin, 1984; Bouchon-Navaro et al. 1985; Roberts and Ormond, 1987) and habitat selection has been demonstrated and discussed as a possible determinant of zonation in coral reef fishes (Williams, 1980; Williams and Sale, 1981; Eckert, 1985).

CHAPTER IV

FOOD AND FEEDING HABITS

FOOD AND FEEDING HABITS

INTRODUCTION

All organisms are clearly dependent on their food sources, and therefore live in areas where they are able to forage effectively. Various reef systems were found to harbour a variety of sub-habitats (Chapter I) characterized by various fish assemblages (Chapter III). A greater diversity of sub-habitats not only provided shelter to some strongly site attached species (e.g., Pomacentridae) but act as substrates for a wide range of algae and invertebrates that form the food for coral reef fishes. Therefore, the abundance of herbivores, omnivores, planktivores and piscivores reflect the availability of their particular diets.

The only available data and information on food preferences of coral reef fishes in India are those from Lakshadweep on damsel fishes, Dascyllus aruanus (Pillai et al., 1985) and Chromis caerulea (Madan Mohan et al. 1986) from the Minicoy atoll. More recent observations on food of Chaetodon auriga, Halichoeres centiguadrus and Dascyllus reticulatus from the Kavaratti and Kalpeni atolls are those of Vijay Anand (1990 a). A short review on important species of ornamental fishes, their habitats and food preferences was given by Vijay Anand and Varghese (1990).

Rangarajan (1970) reported on the food and feeding habits of Lutjanus kasmira from the Andaman sea. Similar studies on some coral reef fishes of Porto Novo (southeast coast of India) were conducted but a

detailed account is not available (Adiyapathalam and Ramaiyan, 1985). In view of the diverse and abundant fish assemblages in the coral reef ecosystems of India (see Chapter II) and the overall paucity of information on food habits of the typical coral reef fishes, the present study was undertaken for 142 commonly occurring species, belonging to 30 families from Lakshadweep and the Gulf of Mannar region.

REVIEW OF LITERATURE

Hiatt and Strasburg (1960) discussed the food and feeding habits of fishes of Marshall Islands belonging to 56 families, 197 genera and 233 species, categorising them as algal feeders, detritus feeders, scavengers, zooplankton feeders, carnivores, coral polyp feeders and omnivores. They also found that items frequently regarded as inedible also constituted significant portions of the diets. In an exhaustive study conducted during 1969 and 1970, Hobson (1974) dealt with the feeding relationships of 102 teleostean fishes on coral reefs in Kona, Hawaii. Certain patterns of behaviour within and between species were observed by Hobson (1965) which permitted tentative generalisations regarding feeding habits, schooling and other activities in relation to time of day. The various feeding patterns among tropical fishes were described by Hobson (1975) while the same from the West Indies were given by Randall (1967). In reviewing various ecological aspects of coral reef fishes, Goldman and Talbot (1976) dealt with aspects of feeding relationships and categorised the modes into herbivores, omnivores, zooplankton feeders, carnivores, detrivores and scavengers. Trophic relationships of reef fishes in Tulear

(Madagascar) were studied by quantitative analysis of stomach contents of 552 fish species belonging to 71 families by Harmelin-Vivien (1981) who found that prey consumption differed in quality and quantity with time and biota. Parrish et al. (1985) roughly quantified trophic relationships for almost all important demersal fishes in the northwestern Hawaiian Islands.

As consumers of primary production, harbivores channel food materials and energy to the remaining members of the food chain. Randall (1965) described the grazing effects on sea grasses by harbivorous reef fishes in the West Indies. The effect of aggressive behaviour of a pomacentrid and an acanthurid, on the intensity of algal grazing were demonstrated by settlement experiments (Vine, 1974). Many reef fishes are stated to be highly selective in the algae they consume and this perhaps is correlated with their morphological and digestive capabilities to rupture algae (Ogden and Lobel, 1978). In a study on the behavioural ecology of three Indian Ocean surgeonfishes, Robertson et al. (1979) claimed that morphological limitation dictated differences in territorality and food habits between the species. In another study from the Western Indian Ocean (Aldabra), Robertson and Polunin (1981) described a three-species system with a damselfish and two larger surgeonfishes where they defended feeding areas against conspecifics and other fishes with similar diet but showed little aggression towards each other. While studying the patterns of fish and urchin grazing on Caribbean coral reefs, Hay (1984) observed Thalassia testudinum (seagrass) to form the food of some reef herbivores, while Thayer et al. (1984) discussed the role that larger herbivores play in seagrass communities. Acanthurids and scarids are selective in their

feeding modes (Wolf, 1985). Partitioning of herbivory and its effects on coral reef algal communities were described by Carpenter (1986). In a recent review on the biology of marine herbivores, Horn (1989) dealt with various aspects of food and feeding and ecological impacts of herbivores. Choat (1991) examined the morphological and other specilizations of herbivores which permit feeding on reef algae.

Siganids are Indo-Pacific herbivores that feed as grazers on filamentous algae or browsers on larger foliose seaweeds (Hiatt and Strasburg, 1960). The food preferences of juvenile Siganus rostratus and S. spinus were studied by Tsuda and Bryan (1973) while aspects of their biology and mariculture potential were discussed by Lam (1974). Selective feeding in Siganus rivulatus and S. luridus was indicated by comparing proportions of plants in diets and vegetation (Lundberg, 1981).

Pomacentridae consists of species that can feed on zooplankton or algae while some tend to be omnivorous. Reese (1978) observed planktovores waiting for food to come to them near the reef edge. In comparing the ecology and osteology of 14 species of damsel fishes, Emery (1973) discussed the distribution and various modes of feeding. Chromis punctipinnis was found to migrate to incurrent ends of the reef to gain better accessibility to zooplankton (Bray, 1981) while the trophic link between the planktonic and rocky reef communities was discussed by Bray et al. (1981). Copepods and larvaceans were principal components of four planktivorous fishes of the genus Chromis (Tribbel and Nishikawa, 1982) while a similar preference in Chromis notatus was observed by Go and Jeon (1983). The diet of Stegastes lividus in Guam was described by Lassuy (1984). Territorial damselfish fed mainly on benthic macroalgae

(Robertson, 1984). Hamner et al. (1988) proposed that planktivorous fishes on the windward reef face form a 'wall of mouths' that remove most of the zooplankton from the water.

Apogonids and holocentrids are among the dominant groups of nocturnal fishes. Vivien and Peyrot-Clausade (1974) compared the feeding behaviour of three holocentrids with reference to the polychaetes of the reef cryptofauna as prey. Prey-species diversity for few species of holocentrids indicated food resource and habitat overlap (Gladfelter and Johnson, 1983). Among the six species of tuna baifish examined for diet and prey selection, a single species of apogonid, Archamia zosterophora predominently consumed crustaceans from nectonic zooplankton (Milton et al. 1990).

Chaetodontids have been extensively studied for their distribution and feeding patterns due to their association with corals. Studies on the foraging behaviour of Chaetodon capistratus and C. aculeatus indicated the former to be a browser on anthozoans while the latter is a predator on invertebrates (Birkeland and Neudecker, 1981). C. miliaris, a Hawaiian endemic butterflyfish fed mainly on calanoid copepods (Ralston, 1981), while C. trifascialis and C. trifasciatus are obligate coral predators (Reese, 1981). Analysis of feeding diets in 18 chaetodontids from the coral reefs of Moorea led to forming four groups, namely, obligate coral feeder, facultative coral feeder, benthic invertebrate and plankton feeders (Harmelin-Vivien and Bouchon-Navaro, 1983). The species richness and individual abundance of butterflyfishes increased with coral density (Findley and Findley, 1985) perhaps due to their dependence on corals for

food. Examination of diets in Chaetodon capistratus indicated that diet composition varied at two different geographic areas studied (Lasker, 1985). Chaetodontids and pomacanthids fed on prey which are noxious or toxic to other reef fishes (Neudecker, 1985). Chaetodontids having a similar diet were found to be localised on different parts of the reef (Bouchon-Navaro, 1986). The relationship between chaetodontid fishes and coral communities were discussed by Bouchon-Navaro and Bouchon (1989). Diets of butterfly fishes from Tulear (southwest Madagascar), Moorea (French Polynesia) and Guada loupe (West Indies) were analysed and the relative abundance of each prey item was expressed in percentages. In a review on environmental determinants of butterflyfishes, Hourigan (1989) stated a generalised diet will increase the apparent evennes of resource distribution. Irons (1989) demonstrated preferences on other coral species apart from Acropora spp. in the obligate coral feeder, Chaetodon trifascialis. To determine the important food recourse, Sano (1989) examined stomach content data of 32 species of chaetodontids from Japan and categorised them as specialists or generalists.

Carnivores constitute a dominant category among reef fishes. One of the earliest work on food habits of such fishes was that of Randall and Brock (1960) who examined stomach conents of 16 species of epinepheline and lutjanid fishes of Society Islands. Fishes, benthic crustaceans and other invertebrates were observed in a quantitative analysis of stomach contents of 8 species of serranids and 17 species of scorpaenids from Tulear (Harmelin-Vivien and Bouchon, 1976). Out of 52 coral reef piscivores from 16 families, 20 species were termed major piscivores and

32 as minor piscivores (Parrish et al., 1986). Fishes, crustaceans and other invertebrates were observed as stomach contents of Lutjanus bohar at Papua New Guinea (Wright et al., 1986). A review by Parrish (1987) on characteristics of fish communities on coral reefs and the interacting shallow habitats, stated that carnivores dominated all habitats, usually with benthic invertebrates as the major prey group while Jones et al. (1991) reviewed the feeding ecology of numerous reef fishes which feed upon other benthic animals.

Wrasses (Labridae) in general feed on benthic invertebrates. Thompson and Jones (1983) discussed certain aspects of diet overlap of the blennoid fish, Forsterygion varium and the wrasse, Pseudolabrus celidotus. In a study which was more based on habitat and behavioural interactions, certain aspects of food preferences of P. celidotus were discussed (Jones, 1984). The benefits of heterospecific foraging by wrasses along with mullids were studied by Aronson and Sanderson (1987). The larger benthic feeding fishes (e.g., Labridae, Mugiloididae) were less likely to feed among macroscopic algal strands (Choat and Ayling, 1987). Verigina and Kobegenova (1987) described the digestive tract morphology which suits the intake of hardshelled prey in labrids.

Prey items (algae, invertebrates and vertebrates) of coral reef fishes are of great importance in the trophic structure. Bakus (1964) discussed various effects of fish grazing on invertebrate evolution in shallow tropical waters, while Greenway (1974) described cropping effects on the seagrass, Thalassia testudinum. Two other studies related to seagrass are those on fish diets in relation to macrobenthic and cryptic

faunal abundance (Brook, 1977) and vertically migrating zooplankton and their fish predators (Robertson and Howard, 1978). Studies conducted at Lakshadweep were those of Madhu Pratap et al. (1977) on abundance of zooplankton in the outer sea and lagoons (that could possibly affect zooplanktivorous fish). In a study on trophic interactions between marine decapod crustaceans and reef fish, Parrish et al. (1986) found that crabs were important prey for more than 30 fish species. Kuile (1989) examined the stomach contents of Myripristis murdjan, Mullodichthys auriflamma and Caesio caerulaureus and discussed about their forage base. Noda Mikio et al. (1992) described the importance of zooplankton patches in foraging ecology of Chromis chrysurus.

Deteriorating reef conditions due to human induced changes may reflect on fish assemblages by effecting their habitats and food resources. Clements and Livingston (1983) described the pollution induced variability in the feeding habitats of filefish (Monacanthidae) from Florida. Changes in predator abundance and herbivore behaviour after hurricane disturbances were observed near Discovery Bay in Jamaica (Kaufman, 1983). The abundance of corallivores on the reef is correlated with their food resources as would be expected if food resources were major determinants of fish distributions (Hourigan et al., 1988). Naesje et al. (1991) found that fish moved to profitable areas several days after food availability changed, while Warwick and Clarke (1993) found increased variability as a symptom of stress in marine communities.

MATERIAL AND METHODS

Fish collections were mainly made by the investigator and his local team using encircling and drive-in-nets. Nocturnal fishes were collected using hooks and lines, gill nets and by stunning fishes using lights (Chapter VI). Collections were supplimented by obtaining samples from large non-selective seine nets operated by the fishermen while specimens from other islands of Lakshadweep and the Gulf of Mannar region were collected on a regular basis with other assistance.

A total of 143 commonly occurring fish species were examined for their qualitative and quantitative prey preferences. After measuring the standard length of the specimens, they were carefully cut open and entire gut contents were analysed. Total lengths were not used owing to a high variation in shapes and breakage of the caudal fins. In the case of occasional large samples, the guts were preserved in 5% formalin or a deep freezer. The points and the number methods were used to determine the relative abundance of each prey item (Hynes, 1950; Pillay, 1952). Harmelin-Vivien (1989) studied the gut contents of chaetodontids where the main prey were sorted by systematic groups and their relative importance was determined by points expressed as percentage. In majority of the coral reef fishes sampled, only few food items were present. All prey items for each specimen were tabulated and allotted points. The summation of points were averaged and transformed into percentage. Harmelin-Vivien (1976) states that the averaged results are more truely representative of the prey categories than the results obtained separately for each species.

In planktivores and omnivores where food items were generally diverse, a sub-sample was used to count all prey. The numbers obtained for each category were considered as points whose summation was averaged and expressed as percentage.

To estimate the diversity of the diets of each species, the Shannon-Weiner Index (H') was calculated as,

$$H' = - \sum pi \quad Log_2 \; pi$$

Where pi is the percentage proportion of a particular prey category for N categories. The index increases according to the number of prey consumed. The lower the index, the more specialized the diet. This method was adopted from Bouchon-Navaro (1986) with a modification in the use of percentage proportion in place of weight proportion. A similar procedure was used by Harmelin-Vivien (1976). Sano (1989) also used H' on the mean volumentric percentage of food to compare the specialist or generalist tendency among species.

Obtaining sufficient sample sizes of coral reef fish is extremely difficult. Therefore fish species of adequate sample sizes were only used from the Gulf of Mannar collections. The analytical procedures were same as mentioned earlier in this section. Food habits of the same species in Lakshadweep and Gulf of Mannar are discussed separately.

RESULTS

A. FOOD AND FEEDING HABITS OF CORAL REEF FISHES OF LAKSHADWEEP

Information on prey preferences and feeding diversity (H') of 142 commonly occurring species of coral reef fishes belonging to 30 families from Lakshadweep is given in this account.

1. Acanthuridae: Food preferences and feeding diversity of 11 acanthurids are given in Table 29. Acanthurus dussumieri fed predominantly on green algae (20.00%) and filamentous algae (11.80%) while seagrass (4.80%) was occassionally present (Fig. 27 A). A. leucosternon, A. mata and A. xanthopterus fed exclusively on green algae that formed proportions of 12.00, 9.40 and 21.90% respectively (Fig. 27 B, D & G), Crustaceans formed a rare food item in A. xanthopterus. A. lineatus preferred green algae (23.60%) followed by filamentous algae (8.42%). Brown algae were occassionally present (Fig. 27 C). Brown algae constituted the main diet of A. nigricauda and Naso lituratus forming 38.20 and 56.50% of stomach contents respectively (Fig. 27 E & I). N. lituratus was occassionally found to feed on seagrass (2.40%) and crustaceans (1.00%). Green algae (80.40%) was the major food item of A. triostegus but it occassionally fed on filamentous algae also (Fig. 27 F). Relatively more crustacean remains (17.40%) were encountered in Ctenochaetus strigosus while other food items that occurred occassionally were polychaetes, shrimp and brown algae with proportions ranging from 1.40 to 2.60% (Fig. 27 H). Naso

unicornis fed predominantly on green algae (48.30%) followed by brown algae (20.60%). Occassional food items were chaetognaths, polychaetes and megalopae (Fig. 27 J). Filamentous algae (43.80%) and green algae (31.60%) formed major stomach constituents in Zebrasoma veliferum (Fig. 27 K). Semidigested matter composed of unidentifiable plant matter and sediment censtituted an important stomach content in all acanthurids.

Feeding diversity (H') of each acanthurid is given in Fig. 30 A. Naso unicornis recorded the highest diversity of 1.84. Five other species with relatively high H' values were A. nigricauda (1.56), Zebrasoma veliferum (1.55), Naso lituratus (1.53), A. dussumieri (1.45) and A. lineatus (1.33). Least feeding diversity was observed in A. leucosternon (0.53) and A. mata (0.45), while that in A. xanthopterus and A. triostegus were comparable (0.83 and 0.82 respectively). Ctenochaetus strigosus recorded a feeding diversity of 1.06.

2. Apogonidae: Food preferences and feeding diversity (H') of six apogonids are given in Table 30. Major stomach contents of Apogon fraenatus were decapod larvae (26.00%) and copepods (20.20%), while megalopae (14.60%) and shrimps (12.00%) also formed important constituents (Fig. 28 A). Fish and crabs were also common (7.40 and 6.80% respectively) and algal fronds (2.00%) rarely occurred. A. taeniophorus also showed similar food preferences but with an interchanged order of preference. Copepods (33.20%) formed major stomach contents followed by

shrimp (23.50% and decapod larvae (18.40%). Fish and megalopae commonly occurred in the diet (9.70 and 6.00% respectively) while crabs and algal fronds were recorded rarely (Fig. 28 E).

Copepods, crabs, shrimp, megalopae, fish and decapod larvae were preferred almost equally by A. kallopterus with proportions ranging between 9.00 to 12.30%, while algal fronds (3.00%) and polychaete larvae occurred occassionally (Fig. 28 B). Amphipods (43.60%) dominated the stomach contents of A. leptacanthus, while crabs (21.25%), megalopae (11.80%) and algal fronds (9.40%) were also important food items. Polychaete larvae (3.33%) were occassionally recorded (Fig. 28 C).

Crabs, amphipods and shrimp (30.40, 23.80 and 12.30% respectively) formed dominant food items in A. quadrifasciatus, while megalopae (9.00%) and algal fronds (5.60%) were commonly found. Decapod larvae (1.00%) rarely occurred (Fig. 28 D). Apogonichthys ocellatus mainly preferred copepods (40.00%), while shrimp (14.07%) and megalopae (17.80%) formed important food items. Fish, polychaete larvae, molluscan and decapod larvae were also found in proportions between 1.00 and 5.00% (Fig. 28 F). Proportions of semidigested matter ranged between 7.00 and 33.00%, mainly containing crustacean remains.

Feeding diversities (H') recorded by apogonids were generally above 2.00 (Fig. 30 B). H' values of Apogon kallopteres and A. fraenatus (2.79 and 2.76 respectively) and A. taeniophorus and A.

Table 29 & 30. Percentage occurrence of food items in the guts of various species of Acanthuridae and Apogonidae. (Number of fishes (N), size ranges in mm, feeding diversity - H').

SPECIES				FOOD ITEMS										
TABLE 29	ACANTHURIDAE	N	SIZE RANGE (mm)	G.ALGA	F.ALGA	B.ALGA	CRUS.R	S.GRAS	CHAETG	MEGLOP	SRIMP	POLYCH	SDM	H'
1.	Acanthurus dussumieri	43	100 - 270	20.00	11.80	-	-	4.80	-	-	-	-	63.40	1.45
2.	A. leucosternon	67	80 - 170	12.00	-	-	-	-	-	-	-	-	88.00	0.53
3.	A. lineatus	38	130 - 200	23.60	8.40	3.80	-	-	-	-	-	-	64.18	1.33
4.	A. mata	35	100 - 220	9.40	-	-	-	-	-	-	-	-	90.60	0.45
5.	A. nigricauda	40	115 - 250	25.00	-	38.20	-	-	-	-	-	-	36.80	1.56
6.	A. triostegus	100	25 - 130	80.40	2.62	-	-	-	-	-	-	-	16.98	0.82
7.	A. xanthopterus	62	112 - 119	21.90	-	-	0.10	-	-	-	-	0.70	77.30	0.83
8.	Ctenochaetus strigosus	15	180 - 240		-	1.40	17.40	-	-	-	1.80	2.60	76.80	1.06
9.	Naso lituratus	6	160 - 192	10.28	-	56.50	1.00	2.40	-	-	-	-	29.82	1.53
10.	N. unicornis	6	296 - 343	48.30	-	20.60	-	-	4.20	0.70	-	2.40	23.80	1.84
11.	Zebrasoma veliferum	13	35 - 172	31.60	43.80	-	-	-	-	-	-	-	24.60	1.55

TABLE 30	APOGONIDAE	N	SIZE RANGE (mm)	COPEP	CRAB	SRIMP	MEGLOP	MOLU.L	POLY.L	ALGA.F	FISH	DECA.L	AMPHI	SDM	H'
1.	Apogon fraenatus	20	45 - 50	20.20	6.80	12.00	14.60	-	-	2.00	7.40	26.00	-	11.00	2.76
2.	A. kallopterus	16	52 - 55	11.57	11.00	9.33	12.30	-	1.00	3.00	9.00	9.80	-	33.00	2.79
3.	A. leptacanthus	19	62 - 69	-	21.25	-	11.80	-	3.33	9.40	-	-	43.60	10.62	2.17
4.	A. quadrifasciatus	13	39 - 60	-	30.40	12.30	9.00	-	-	5.60	-	1.00	23.80	17.90	2.43
5.	A. taeniophorus	46	22 - 63	33.20	1.00	23.50	6.00	-	-	1.10	9.70	18.40	-	7.10	2.45
6.	Apogonichthys ocellatus	14	33 - 41	40.00	-	14.07	17.80	2.00	4.83	-	5.00	1.00	-	15.30	2.39

ALGAE.F - algal fragments, AMPHI - amphipods, B.ALGA - brown algae, CRAB - crabs, CHAETG - chaetognaths, COPEP - copepods, CRUS.R - crustacean remains, DECA.L - decapod larvae, F.ALGA - filamentous algae, FISH - fish, G.ALGA - green algae, SEGLOP - crab megalopae, MOLU.L - molluscan larvae, POLY.L - polychaete larvae, POLYCH - polychaetes, S.GRAS - seagrass, SRIMP - shrimp, SDM - swmidigested matter.

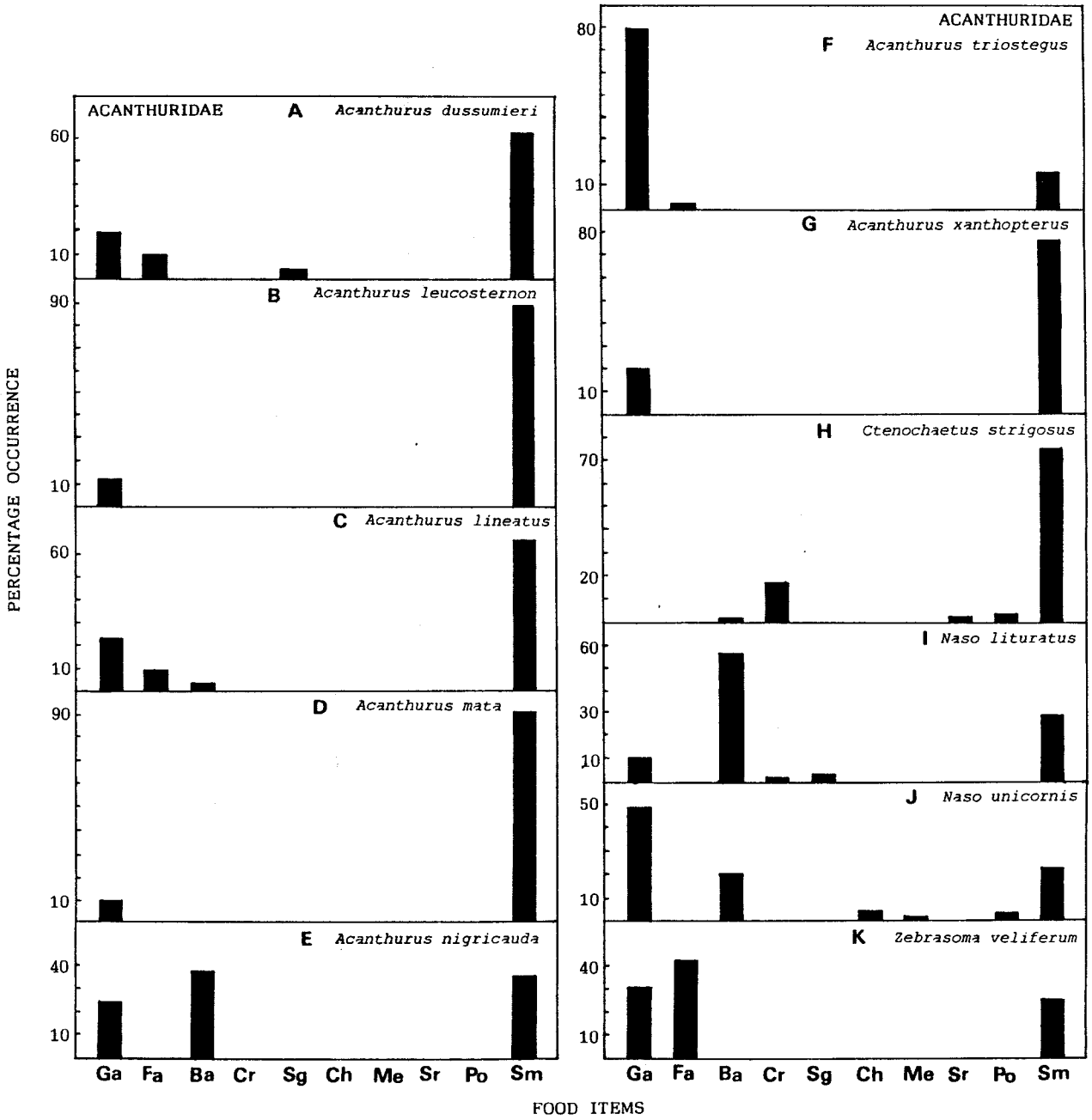

Figure 27. Percentage occurrence of food items in the guts of eleven acanthurid species.
(Ga - Green algae, Fa - filamentous algae, Ba - brown algae, Cr - crustacean remains, Sg - seagrass, Ch - chaetoganths, Me - megalopae, Sr - shrimp, Po - polychaetes, Sm - semidigested matter).

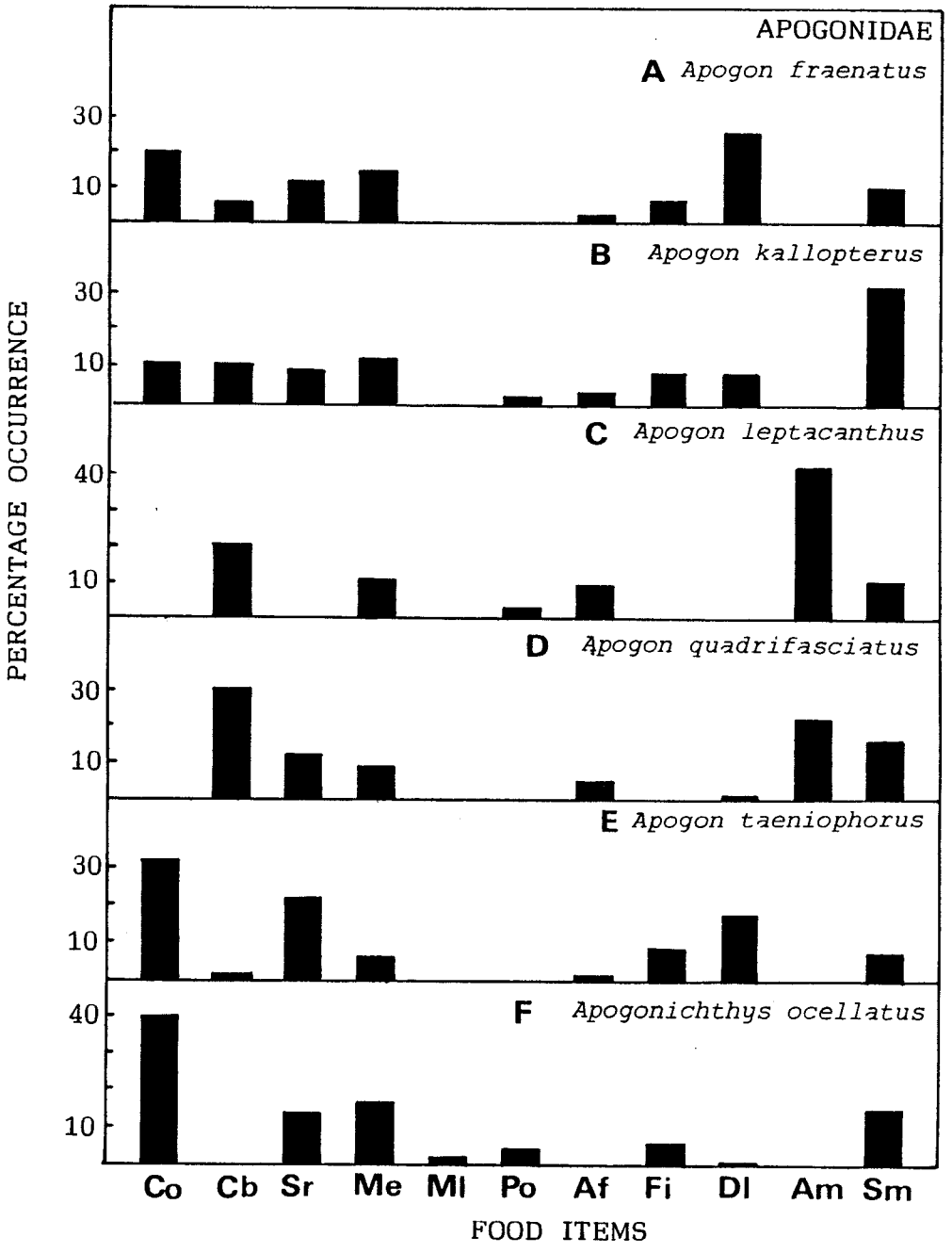

Figure 28. Percentage occurrence of food items in the gut contents of seven apogonid species.

(Co - copepods, Cb - crabs, Sr - shrimp, Me - megalopae, Ml - molluscan larvae, Po - polychaetes, Af - algal fragments, Fi - fish, Dl - decapod larvae, Am - amphipods, Sm - semidigested matter).

guadrifasciatus (2.45 and 2.43 respectively) were comparable. H' values in Apogonichthys ocellatus and Apogon leptacanthus were 2.39 and 2.17 respectively.

3. Balistidae: Food preferences and feeding diversity (H') of 11 balistids are given in Table 31. Balistapus undulatus fed mainly on fish (43.00%) followed by alpheid shrimp (16.76%). Stomatopods (8.30%) and crabs (2.34%) were occassional diets (Fig. 29 A). Crabs (76.80%) dominated stomach contents of Balistoides viridescens. Alpheid shrimp (16.50%) also formed an important constituent while sea urchins and pelecypods (2.70 and 1.10% respectively) were consumed occassionally (Fig. 29 B). Canthedermis maculatus was found to prefer fish and copepods (25.00 and 25.70% respectively) almost equally, while mysids (4.80%) and shrimp (1.81%) were rare food items (Fig. 29 C). Melichthys indicus fed mainly on crabs (35.00%) while stomatopods (18.70%), algae (14.80%) and fish (8.60%) formed important stomach constituents. Shrimp was occasionally consumed (Fig. 29 D). Odonus niger exhibited a broader feeding niche, preferring shrimps (19.90%), amphipods, copepods (15.00% each) and mysids (12.60%). Crabs and fish accounted for 5.60 and 5.20% of the stomach contents while sea urchin remains, alpheid shrimp and ostracods occurred in proportions of 2.30, 1.00 and 0.40% respectively (Fig. 29 E).

Crabs formed the major food item in Pseudobalistes flavimarginatus, Rhinecanthus aculeatus, R. rectangulus, Sufflamen

bursa, S. chrysopterus and S. fraenatus forming proportions between 50.00 and 73.00%. Only S. fraenatus recorded the occurrence of amphipods (1.22%). Stomatopods (8.87%), alpheids (10.40%) and algae (12.80%) were found in the guts of P. flavimarginatus. Apart from crabs, S. chrysopterus, fed on alpheids (9.80%) and pelecypods (1.40%), with the latter also recorded from R. rectangulus (1.05%). Sea urchin remains, stomatopods and alpheids were common in stomach contents of R. aculeatus, R. rectangulus and Sufflamen bursa but with varying proportions (Fig. 29, F, G, H, I, J & K). Semidigested matter varied greatly with species accounting for proportions between 2.00 and 43.00%.

Feeding diversities (H') of each balistid species is given in Fig. 30 C. All species recorded H' values above 1.00. Odonus niger and Melichthys indicus accounted for high feeding diversity (2.83 and 2.34 respectively), while the least was found in Balistoides viridescens (1.08) and Sufflamen chrysopterus (1.22). Other species accounted for H' values between 1.60 and 1.90 except Rhinecanthus aculeatus which indicated 1.40.

4. Caesionidae: A total of 56 individuals of Caesio caerulaureus of the size range 98 to 165 mm were studied. Copepods (66.34%) were dominant among the food items, followed by fish (14.74%). Decapod larvae, molluscan larvae, ostracods, chaetognaths and mysids formed proportions of 5.08, 4.00, 3.42, 1.17 and 0.15%

respectively. Semidigested matter was however low in proportion (5.10%) mainly consisting of crustacean remains (Fig. 34 G). The feeding diversity was 1.60.

5. Chaetodontidae: Food preferences and feeding diversity (H') of 15 chaetodontid species are given in Table 32. Coral polyp remains (41.60%) dominated food items in Chaetodon auriga. Polychaete tentacles (25.72%) and filamentous algae (20.80%) were important constituents in the diet. Remains of amphipods (4.63%), sponges (1.20%) and sipunculids (0.10%) were occassional food items (Fig. 31 A). C. citrinellus and C. collare fed predominantly on filamentous algae (53.85 and 75.00% respectively) and polychaete tentacles (15.62 and 12.80% respectively). Coral polyp and sponge remains were also common in the diets of C. citrinellus with proportions of (7.85 and 8.78% respectively) as compared to that in C. collare (1.60 and 5.60% respectively). Sipunculid remains (1.30%) from C. citrinellus and amphipods (2.30%) from C. collare were also recorded (Fig. 31 B & C).

Polychaete tentacles formed more than 40.00% of the food items in C. falcula, C. lunula and C. melannotus. Other common food items in C. falcula were coral polyps (19.00%) and sponges (10.20%). Filamentous algae and molluscs formed propotions of 5.10 and 4.30% respectively (Fig. 32 A). C. lunula and C. melannotus also fed on filamentous algae (11.77 and 28.00% respectively) and coral polyps (12.00 and 1.40% respectively). C. lunula was also found to feed on amphipods, decapod larvae,

copepods, molluscs and eggs which formed proportions of 4.30, 3.30, 2.63, 1.30 and 0.54% respectively (Fig. 32 C & D). C. kleinii indicated a different food preference with copepods (28.15%), amphipods (26.86%) and sponges (15.60%) as major food items. Filamentous algae (10.15%), decapod larvae (7.44%) and eggs (3.20%) were also present among stomach contents (Fig. 32 B). C. trifascialis and C. trifasciatus showed similar food preferences. The former fed on coral polyps (33.80%) followed by polychaete tentacles (8.63%) and filamentous algae (5.14%) while the latter preferred polychaete tentacles (26.75%), coral polyps (20.20%) and sponges (15.00%). Filamentous algae (4.65%) was commonly consumed by C. trifasciatus (Fig. 32 E & F). Coral polyps, polychaete tentacles and filamentous algae formed the diet of C. vagabundus accounting for proportions of 75.21, 6.40 and 8.30% respectively (Fig. 32 G). Filamentous algae (56.80%) and polychaete tentacles (21.43%) dominated among the stomach contents of C. xanthocephalus. Sponges (8.00%) and coral polyp remains (3.67%) were occasionally recorded. Eggs (0.10%) were rare in occurrence (Fig. 32 H).

The two species belonging to genus Forcipiger, F. flavissimus and F. longirostris mainly fed on shrimp (83.50 and 89.38% respectively). Decaped larvae (8.48%) and amphipods (5.40%) were other food items recorded from F. flavissimus (Fig. 32 I & J). Filamentous algae formed the dominant stomach content in Heniochus acuminatus and H. monoceros forming proportions of 38.00 and

48.30% respectively. Amphipods (20.10%), decapod larvae (5.68%) and polychaete tentacles (2.37%) were commonly recorded in H. acuminatus. Copepods and eggs were rare (0.10% each) in occurrence (Fig 32 K). Apart from filamentous algae, H. monoceros fed on copepods, coral polyps, sponges, sipunculid remains and decapod larvae that formed proportions of 13.70, 8.20, 4.30, 4.00 and 1.00% respectively (Fig. 32 L). Semidigested matter varied greatly in proportion with species (2.00 to 34.00%).

Feeding diversity (H') of each chaetodontid species is shown in Fig. 33 A. H' values recorded were generally above 1.00 except in Forcipiger flavissimus and F. longirostris where it was 0.89 and 0.43 respectively. Six species, namely C. auriga, C. falcula, C. kleinii, C. lunula, C. trifasciatus and Heniochus monoceros accounted for H' values above 2.00. C. kleinii showed the highest diversity of 2.51 while in others it ranged between 2.04 to 2.16. H' in C. citrinellus and Heniochus acuminatus was comparable (1.96 and 1.92 respectively). C. collare, C. melannotus, C. trifascialis and C. xanthocephalus recorded H' values between 1.29 and 1.74.

6. Cirrhitidae: Six individuals of Cirrhites pinnulatus in the size range of 80 to 85 mm were examined. Three food items, namely, crabs (74.10%), fish (3.40%) and shrimp (2.20%) were observed (Fig. 34 B). 23 individuals of Paracirrhites forsteri in the size range of 52 to 104 mm were examined. Only fish and shrimp were recorded from the stomach contents forming proportions of 52.80

Table 31 & 32. Percentage occurrence of food items in the guts of various species of Balistidae and Chaetodontidae. (Number of fishes (N), size ranges in mm, feeding diversity - H').

	SPECIES			FOOD ITEMS													
TABLE 31	BALISTIDAE	N	SIZE RANGE (mm)	CRAB	AMPHI	S.URCH	STOMAP	ALPHE	PELCY	COPEP	MYSID	SRIMP	OSTRA	FISH	ALGA	SDM	H'
1.	Balistapus undulatus	16		2.34	-	-	8.30	16.76	-	-	-	-	-	43.00	-	29.60	1.90
2.	Balistoides viridescens	36	105 - 132	76.80	-	2.70	-	16.50	1.10	-	-	-	-	-	-	2.60	1.08
3.	Canthedermis maculatus	3	102 - 110	-	-	-	-	-	-	25.70	4.80	1.81	-	25.00	-	42.69	1.83
4.	Melichthys indicus	60	92 - 120	35.00	-	1.00	18.70	-	-	-	-	2.10	-	8.60	14.80	19.80	2.34
5.	Odonus niger	25	57 - 185	5.60	15.00	2.30	-	1.00	-	15.00	12.60	19.90	0.40	5.20	-	23.00	2.83
6.	Pseudobalistes flavimarginatus	8	55	60.90	-	-	8.87	10.40	-	-	-	-	-	-	12.80	7.03	1.74
7.	Rhinecanthus aculeatus	72	55 - 163	72.20	-	5.25	8.00	6.95	-	-	-	-	-	-	-	7.60	1.40
8.	R. rectangulus	20	92 - 139	60.10	-	11.32	2.00	2.45	1.05	-	-	-	-	-	-	23.08	1.60
9.	Sufflamen bursa	8	135 - 158	50.70	-	8.60	27.50	10.30	-	-	-	-	-	-	-	2.90	1.80
10.	S. chrysopterus	8	92 - 155	70.70	-	-	-	9.80	1.40	-	-	-	-	-	-	18.10	1.22
11.	S. fraenatus	7	162 - 243	62.50	1.22	5.00	0.90	7.40	6.00	-	-	-	-	-	-	16.98	1.73

TABLE 32	CHAETODONTIDAE	N	SIZE RANGE (mm)	F.ALGA	POLY.T	CORL.P	SRIMP	SIPUN	COPEP	AMPHI	EGGS	SPONG	DECA.L	MOLLU	SDM	H'
1.	Chaetodon auriga	125	20 - 132	20.80	25.72	41.60	-	0.10	-	4.63	-	1.20	-	-	5.95	2.04
2.	C. citrinellus	43	52 - 107	53.85	15.62	7.85	-	1.30	-	-	-	8.78	-	-	12.60	1.96
3.	C. collare	96	72 - 114	75.00	12.80	1.60	-	-	-	2.30	-	5.60	-	-	2.70	1.29
4.	C. falcula	18	40 - 153	5.10	46.00	19.00	-	-	-	-	-	10.20	-	4.30	15.40	2.16
5.	C. kleinii	7	61 - 85	10.15	-	-	-	-	28.15	26.86	3.20	15.60	7.44	-	8.60	2.51
6.	C. lunula	27	90 - 113	11.77	54.00	12.00	-	-	2.63	4.30	0.54	-	3.30	1.30	10.16	2.13
7.	C. melannotus	40	60 - 90	28.00	63.25	1.40	-	-	-	-	-	-	-	-	7.35	1.30
8.	C. trifascialis	10	105 - 120	5.14	8.63	33.80	-	-	-	-	-	-	-	-	52.43	1.55
9.	C. trifasciatus	36	25 - 105	4.65	26.75	20.20	-	-	-	-	-	15.00	-	-	33.40	2.13
10.	C. vagabundus	12	82 - 111	8.30	6.40	75.21	-	-	-	-	-	-	-	-	10.09	1.19
11.	C. xanthocephalus	30	27 - 168	56.80	21.43	3.67	-	-	-	-	0.10	8.00	-	-	10.00	1.74
12.	Forcipiger flavissimus	4	100 - 130	-	-	-	83.50	-	-	5.40	-	-	8.48	-	2.62	0.89
13.	F. longirostris	6	122 - 145	-	-	-	89.38	-	-	-	-	-	-	-	10.62	0.48
14.	Heniochus acuminatus	29	48 - 122	38.00	2.37	-	-	-	0.10	20.10	0.10	-	5.68	-	33.65	1.92
15.	H. monoceros	8	93 - 120	48.30	-	8.20	-	4.00	13.70	-	-	4.30	1.00	-	20.50	2.13

ALGA - algae, ALPHE - alpheid shrimp, AMPHI - amphipods, CRAB - crabs, COPEP - copepods, CORL.P - coral polyps, DECA.L - decapod larvae, EGGS - eggs, F.ALGA - filamentous algae, FISH - fish, MOLLU - molluscs, MYSID - mysids, OSTRA - ostracods, PELCY - pelecypods, POLY.T - polychaete tentacles, SIPUN - sipunculids, SPONG - sponges, SRIMP - shrimp, STOMAP - stomatopods, S.URCH - sea urchin remains, SDM - semidigested matter.

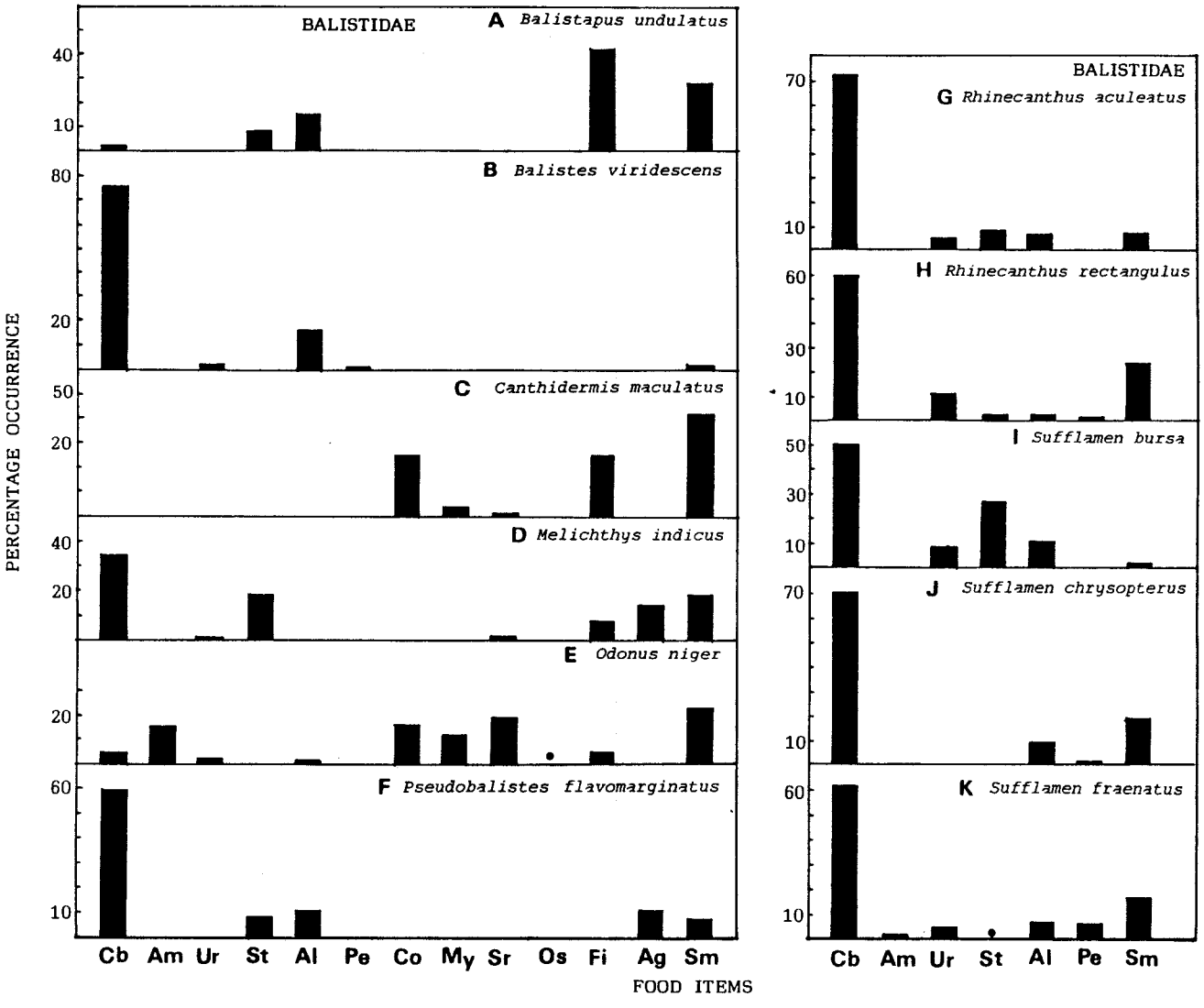

Figure 29. Percentage occurrence of food items in the gut contents of eleven balistid species.

(Cb - crab, Am - amphipods, Ur - sea urchin remains, St - stomatopods, Al - alpheid shrimp, Pe - pelecypods, Co - copepods, My - mysids, Sr - shrimp, Os - ostracods, Fi - fish, Ag - algae, Sm - semidigested matter). • less than 0.5%.

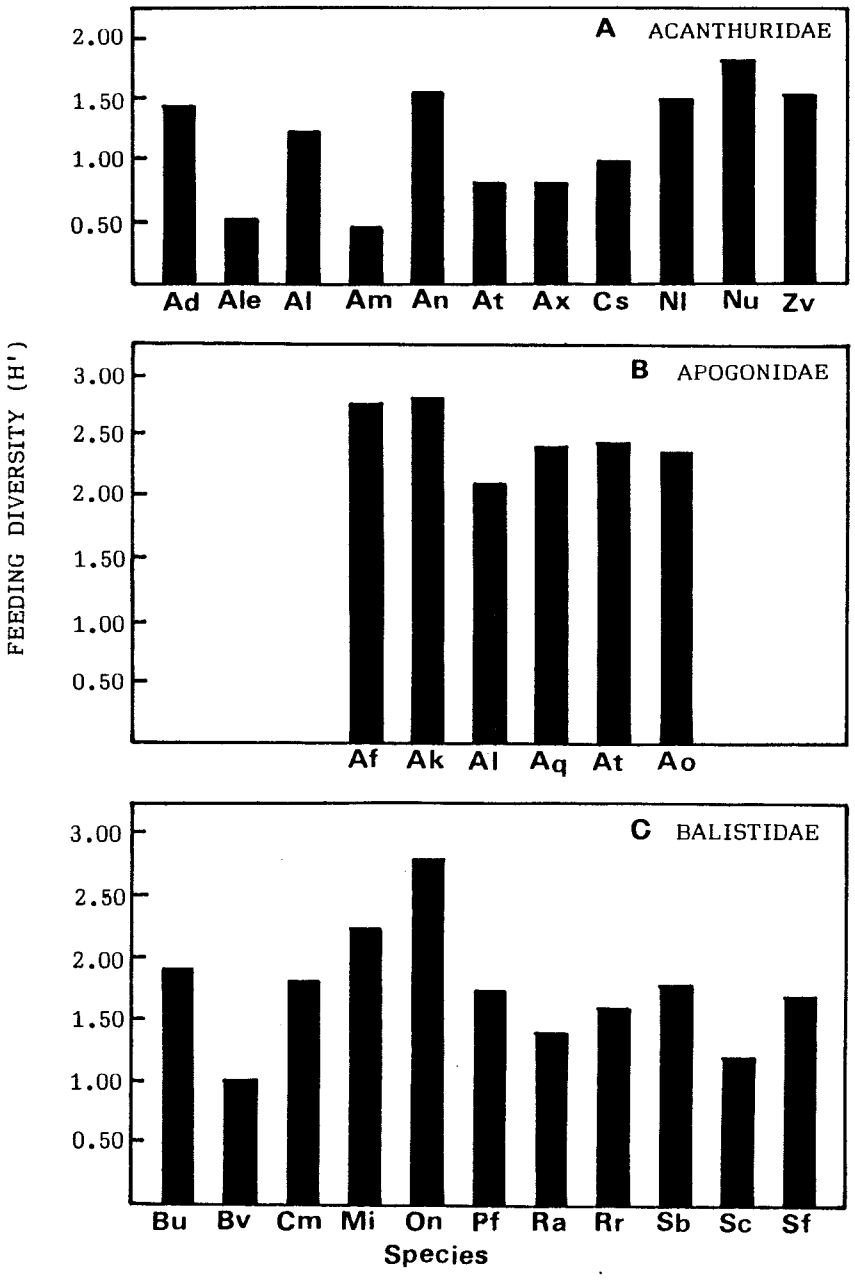

Figure 30. Feeding diversity of various species belonging to families, Acanthuridae (A), Apogonidae (B) and Balistidae (C).

(Ad - Acanthurus dussumieri, Ale - A. leucosternon, Al - A. lineatus, Am - A. mata, An - A. nigricauda, At - A. triostegus, Ax - A. xanthopterus, Cs - Ctenochaetus strigosus, Nl - Naso lituratus, Nu - Naso unicornis, Zv - Zebrasoma velifirum, Af - Apogon fraenatus, Ak - A. kallopterus, Al - A. leptacanthus, Aq - A. quadrifasciatus, At - A. taeniophorus, Ao - Apogonichthys ocellatus; Bu - Balistapus undulatus, Bv - Balistes viridescens, Cm - Canthidermis maculatus, Mi - Melichthys indicus, On - Odonus niger, Pf - Pseudobalistes flavimarginatus, Ra - Rhinecanthus aculeatus, Rr - R. rectangulus, Sb - Sufflamen bursa, Sc - S. chrysopterus, Sf - S. fraenatus).

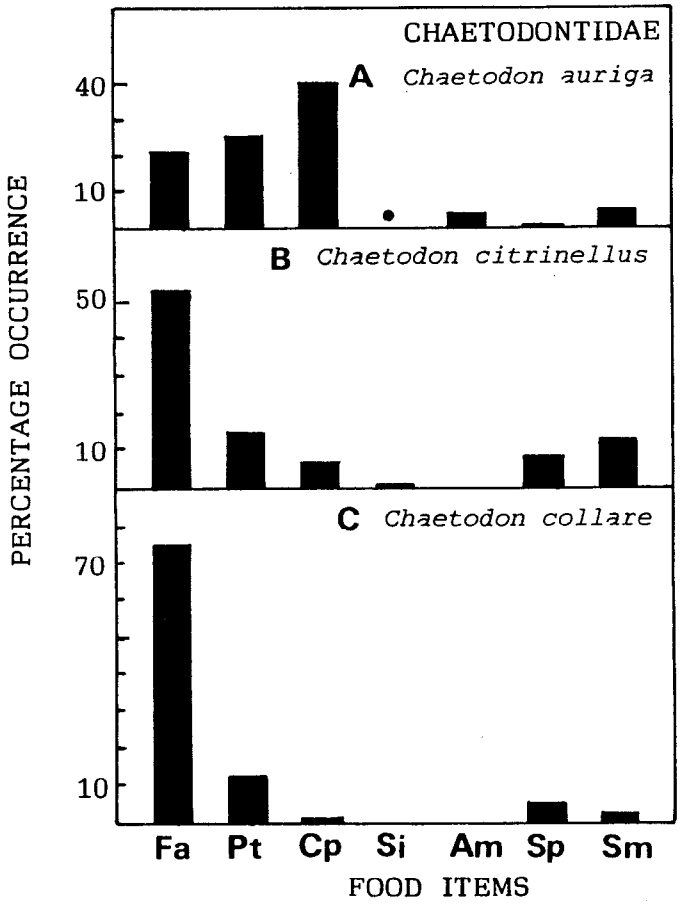

Figure 31. Percentage occurrence of food items in the gut of three chaetodontid species.

(Fa - Filamentous algae, Pt - Polychaete tentacles, Cp - coral polyps, Si - sipunculids, Am - amphipods, Sp - sponges, Sm - semidigested matter) • less than 0.5%.

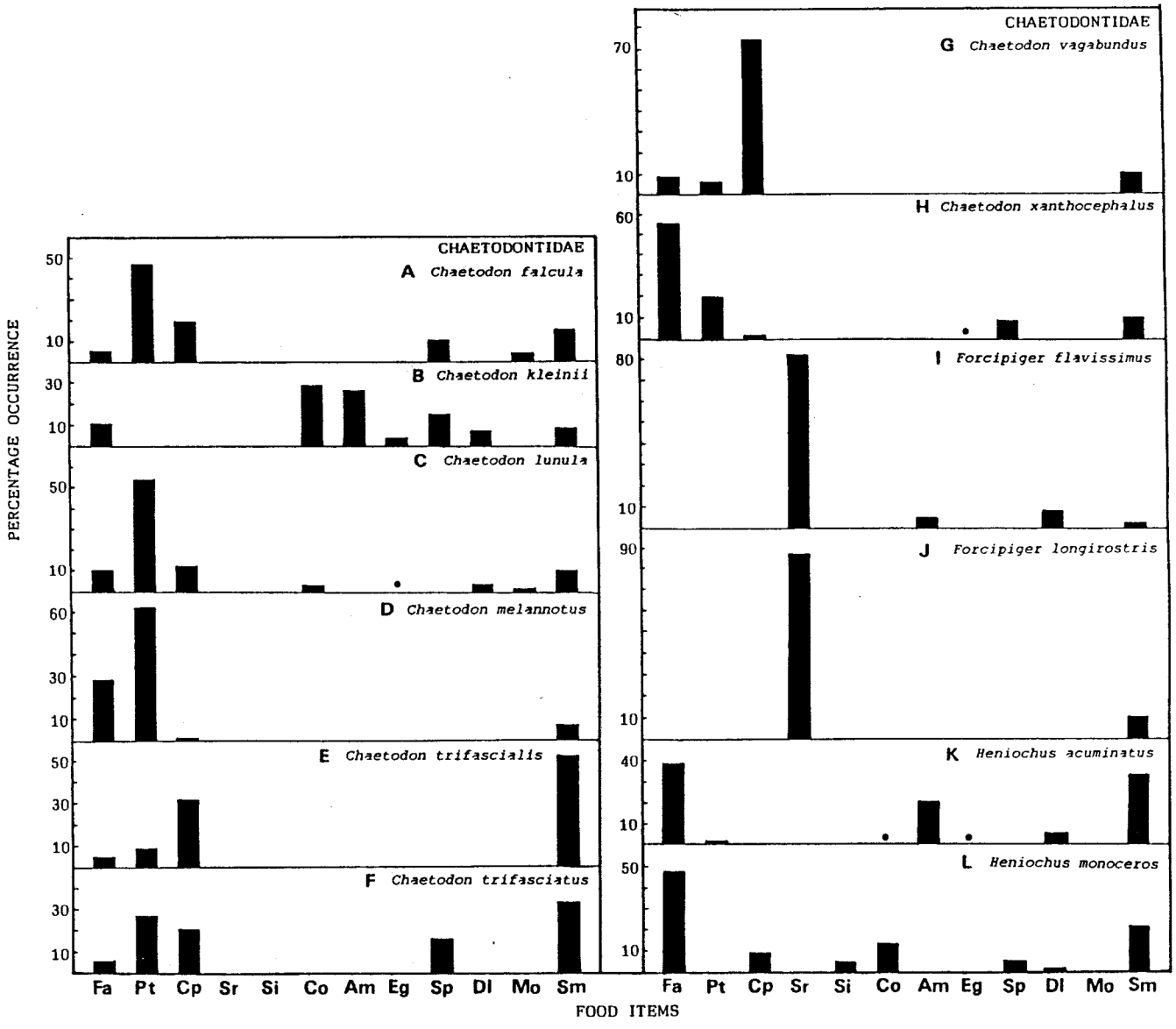

Figure 32. Percentage occurrence of food items in the guts of twelve chaetodontid species.

(Fa - filamentous algae, Pt - polychaete tentacles, Cp - coral polyps, Sr - shrimp, Si - sipunculids, Co - copepods, Am - amphipods, Eg - eggs, Sp - sponges, Dl - decapod larvae, Mo - molluscs, Sm - semidigested matter) • less than 0.5%.

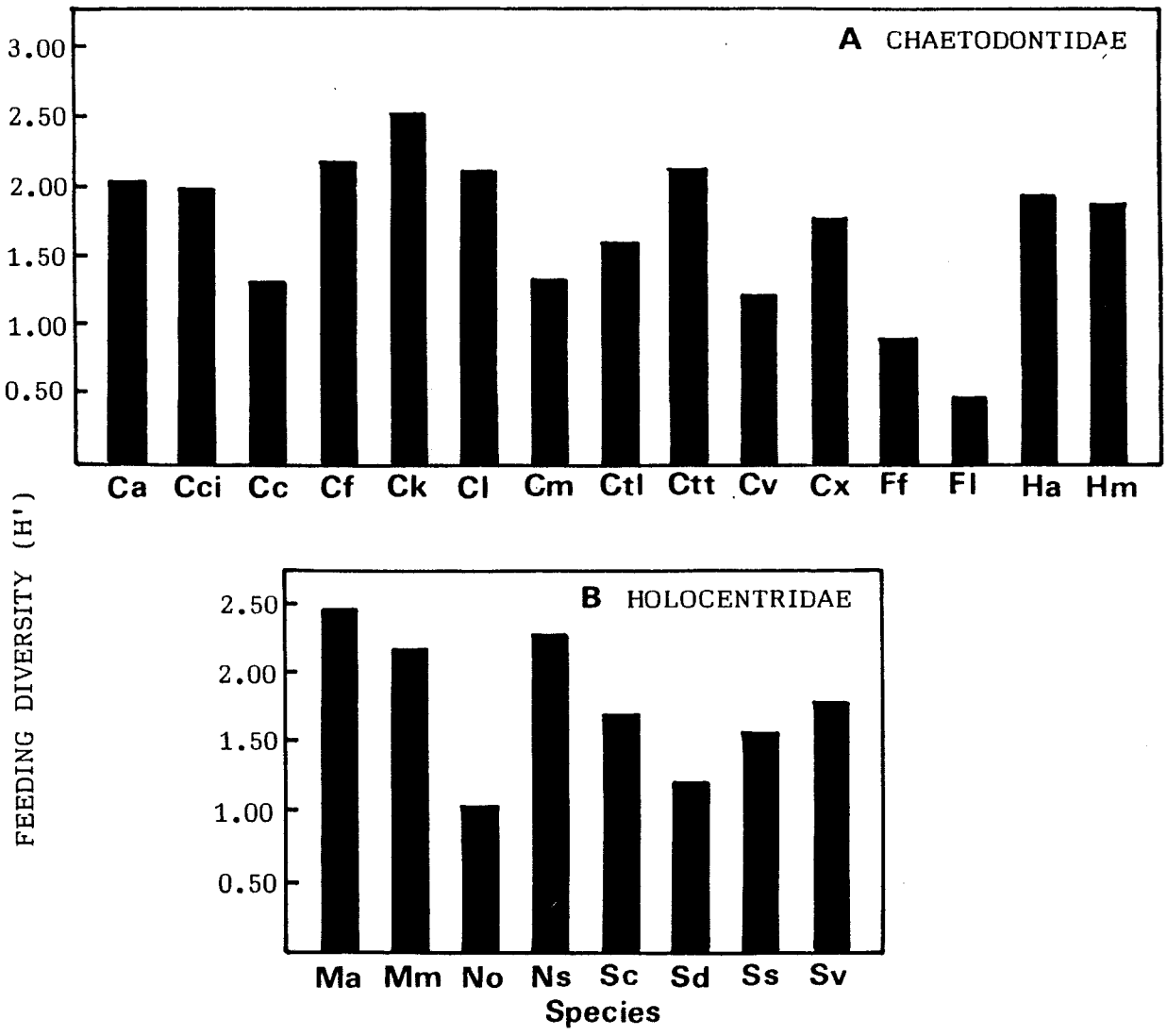

Figure 33. (A & B) Feeding diversity (H') of various species belonging to the families, Chaetodontidae (A) and Holocentridae (B).

(Ca - Chaetodon auriga, Cci - C. citrinellus, Cc - C. collare, Cf - C. falcula, Ck - C. kleinii, Cl - C. lunula, Cm - C. melannotus, Ctl - C. trifascialis, Ctt - C. trifasciatus, Cv - C. vagabundus, Cx - C. xanthocephalus, Ff - Forcipiger flavissimus, Hm - H. monoceros; Ma - Myripristis adusta, Mm - M. murdjan, No - Neoniphon opercularis, NS - N. sammara, Sc - Sargocentron caudimaculatum, Sd - S. diadema, Ss - S. spiniferum, Sv - S. violaceum).

and 12.53% respectively (Fig. 34 C). Semidigested matter in the two species accounted for 20.30 and 34.67% respectively. Of the two, P. forsteri showed a higher feeding diversity (1.40) while C. pinnulatus recorded a H' value of 1.08.

7. Diodontidae: Three individuals of Diodon histrix in the size range of 195 to 260 mm were examined. Coral fragments (42.60%) followed by crustacean remains (23.00%) were the dominant food components. Algal fronds were common with a proportion of 5.30% (Fig. 34 D). Semidigested matter accounted for 29.10%. D. histrix recorded a feeding diversity of 1.75.

8. Fistulariidae: 32 individuals of Fistularia petimba in the size range of 154 to 640 mm were examined. Only two food items; fish (70.50%) and shrimp (3.00%) were observed (Fig. 34 A). Semidigested matter accounted for 26.50%. F. petimba recorded a feeding diversity of 1.02.

9. Grammistidae: Four individuals of Grammistes sexlineatus in the size range of 60 to 109 mm were examined. It fed predominantly on fish (63.40%) followed by crabs (10.75%) and shrimp (5.65%). Semidigested matter accounted for 20.20% (Fig. 41 B). G. sexlineatus accounted for a feeding diversity of 1.47.

10. Haemulidae: 17 individuals of Plectorhinchus gibbosus in the size range of 220 to 520 mm were examined. Fish (46.00%) constituted the main food item. Crabs, sipunculid remains and shrimp formed

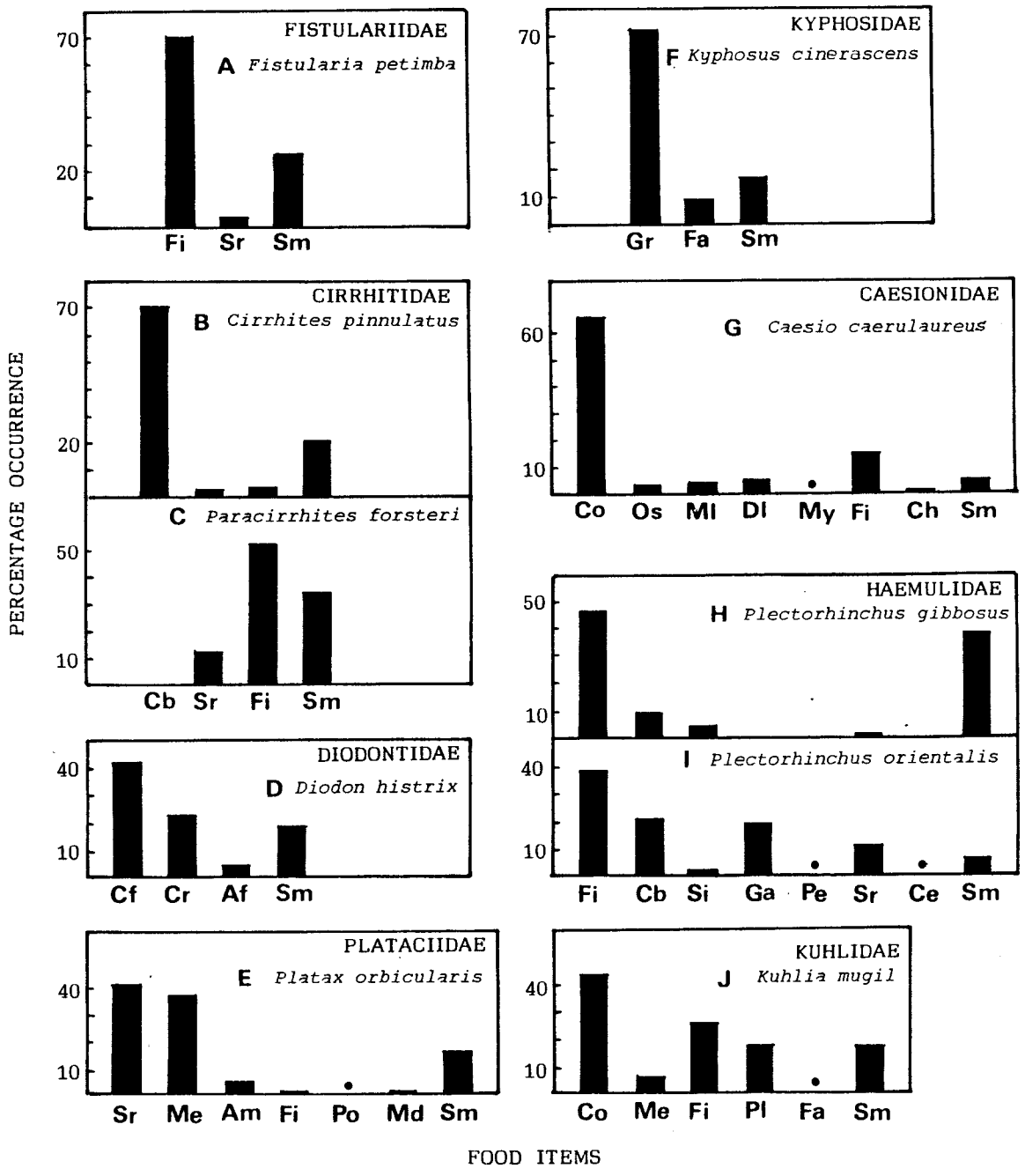

Figure 34. (A to J) Percentage occurrence of food items in the guts of various species belonging to the families, Fistulariidae, Cirrhitidae, Diodontidae, Platacidae, Kyphosidae, Caesionidae, Haemulidae and Kuhlidae.

(Af - algal fragments, Am - amphipods, Cb - crabs, Ce - cephalopods, Ch - chaetognaths, Co - copepods, Cf - coral fragments, Dl - decapod larvae, Fa - filamentous algae, Fi - fish, Ga - green algae, Gr - Gracilaria spp., Me - megalopae, Md - medusae, Ml - molluscan larvae, My - mysids, Os - ostracods, Pl - polychaete larvae, Po - polychaetes, Si - sipunculids, Sr - shrimp, Sm - semidigested matter) • less than 0.5%.

proportions of 9.30, 4.00 and 1.70% respectively. Semidigested matter accounted for 39.00% (Fig. 34 H). 29 individuals of P. orientalis in the size range of 200 to 463 mm were examined. Apart from feeding on fish (39.67%), it showed a wider food niche that was composed of crabs (20.77%), gastropods (18.90%), shrimp (10.40%), sipunculids (2.30%) cephalopods (0.70%) and pelecypods (0.50%). Proportion of semidigested matter was low accounting for 6.76% (Fig. 34 I). P. orientalis recorded a higher feeding diversity (2.27) when compared to 1.66 in P. gibbosus.

11. Holocentridae: Food preferences and feeding diversity (H') of eight holocentrids are given in Table 33. Myripristis adusta and M. murdjan fed predominantly on decapod larvae (39.60 and 45.82% respectively) and copepods (21.70 and 25.00% respectively). In M. adusta, molluscan larvae, fish and shrimp formed important stomach contents with proportions of 11.00, 8.90 and 6.40% respectively. Food items occasionally recorded were chaetognaths, cirriped larvae and eggs forming 3.70, 0.80 and 0.10% of stomach contents respectively (Fig. 35 A & B). Neoniphon opercularis fed on crabs and fish that formed 75.60 and 16.20% of stomach contents respectively (Fig. 35 C). N. sammara mainly preferred crabs (30.00%) followed by fish, shrimp and stomatopods that formed proportions of 23.50, 19.42 and 15.00% respectively (Fig. 35 D).

The four species examined under the genus Sargocentron, namely, S. caudimaculatum, S. diadema, S. spiniferum and S. violaceum mainly preferred crabs in their diets (52.00 to 72.20%).

Fish and shrimp in varying proportions were common in diets of the four species. S. violaceum and S. diadema consumed more fish (19.30 and 15.00% respectively) while in S. caudimaculatum and S. spiniferum it was 7.40 and 9.60% respectively. S. violaceum recorded the least proportion of shrimp (0.70%) while the other three species had proportions between 7.00 and 11.00%. Sipunculids formed an important food item in S. caudimaculatum and S. violaceum (20.60 and 11.30% respectively). Stomatopods (1.52%) were occasionally recorded in S. spiniferum (Fig. 35 E, F, G & H). Semidigested matter normally consisted of fish and crustacean remains accounting for proportions between 2.70 and 16.70%.

Feeding diversity (H') of each holocentrid species is shown in Fig. 33 B. Myripristis adusta recorded the highest feeding diversity of 2.46 followed by Neoniphon sammara (2.25) and M. murdjan (2.17). Least feeding diversity was observed in N. opercularis (1.04). The four species belong to genus Sargocentron showed H' values between 1.20 and 1.79.

12. Kuhlidae: 25 individuals of Kuhlia mugil in the size range of 62 to 114 mm were examined. They mainly fed on copepods (43.62%) and fish (25.30%). Other food items recorded were polychaete larvae, megalopae and filamentous algae forming 8.17, 6.21 and 0.40% of stomach contents respectively. Semidigested matter accounted for 16.30% (Fig. 34 J). K. mugil recorded a feeding diversity of 2.03.

Table 33. Percentage occurrence of food items in the guts of eight holocentrids. (Number of fishes (N), size ranges in mm, feeding diversity - H')

SPECIES				FOOD ITEMS												
TABLE 33	HOLOCENTRIDAE	N	SIZE RANGE (mm)	FISH	CRAB	SRIMP	SIPUN	DECA.L	MOLU.L	CHAETG	EGGS	CIRP.L	STOMAP	COPEP	SDM	H'
1.	Myripristis adusta	6	37 -163	8.90	-	6.40	-	39.60	11.00	3.70	0.10	0.80	-	21.70	7.80	2.46
2.	M. murdjan	130	32 -155	2.60	-	10.50	-	45.82	8.30	0.50	2.00	-	-	25.00	5.28	2.17
3.	Neoniphon opercularis	5	174-283	16.20	75.60	-	-	-	-	-	-	-	-	-	8.20	1.04
4.	N. sammara	43	40 -148	23.50	30.00	19.42	-	-	-	-	-	-	15.00	-	12.08	2.25
5.	Sargocentron caudimaculatum	15	122-196	7.40	60.00	7.00	20.60	-	-	-	-	-	-	-	5.00	1.68
6.	S. diadema	12	73 -180	15.00	72.70	9.60	-	-	-	-	-	-	-	-	2.70	1.20
7.	S. spiniferum	19	200-236	9.60	63.80	10.10	-	-	-	-	-	-	1.52	-	14.98	1.56
8.	S. violaceum	7	104-205	19.30	52.00	0.70	11.30	-	-	-	-	-	-	-	16.70	1.79

CRAB - crabs, CHAETG - chaetognaths, CIRR.L - cirripede larvae, COPEP - copepods, DECA.L - decapod larvae, EGGS - eggs, FISH - fish, MOLU.L - molluscan larvae, SIPUN - sipunculids, SRIMP - shrimp, STOMAP - stomatopods, SDM - semidigested matter.

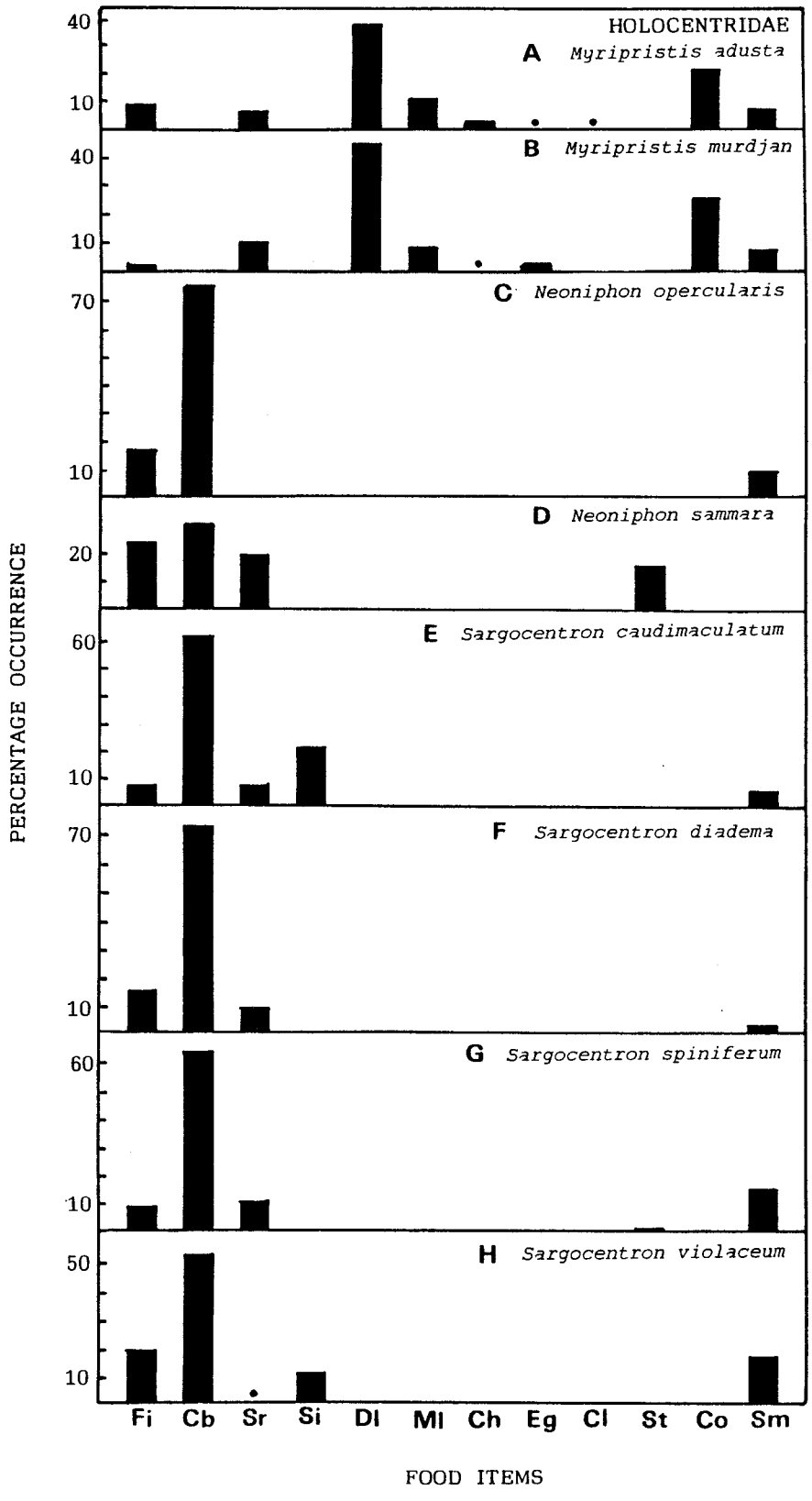

Figure 35. Percentage occurrence of food items in the guts of eight (A to H) holocentrid species.

(Fi - fish, Cb - crabs, Sr - shrimp, Si - sipunculids, Dl - decapod larvae, Ml - molluscan larvae, Ch - chaetognaths, Eg - eggs, Cl - cirripede larvae, St - stomatopods, Co - copepods, Sm - semidigested matter) • less than 0.5%.

13. Kyphosidae: 38 individuals of Kyphosus cinerascens in the size range of 300 to 478 mm were examined. It fed mainly on the sea weed, Gracilaria spp. (72.81%) followed by filamentous algae (9.50%). Semidigested matter accounted for 17.69% (Fig. 34 F). It recorded a feeding diversity of 1.09.

14. Labridae: Food preferences and feeding diversities of 28 labrid species are given in Table 34. Anampses caerulopunctatus fed mainly on crabs (42.90%). Alpheids and gastropods formed important diet components accounting for 16.90 and 11.90% respectively of food items. Other common food items were starfish remains, lobster remains, pelecypods and stomatopods forming proportions of 5.60, 3.80, 3.00 and 2.88% respectively (Fig. 36 A). Fish (60.00%) was the dominant food consumed by Bodianus axillaris apart from crustaceans remains (6.70%) that were recorded occasionally (Fig. 36 B). Crabs were dominant in the diets of Cheilinus chlorurus and C. digrammus with proportions of 33.30 and 56.80% respectively. C. chlorurus preferred gastropods (20.20%) while common food items were stomatopods, sea urchin remains, fish and starfish remains with proportions of 5.00, 3.01, 1.60 and 1.40 respectively. Shrimp were occasionally consumed (Fig. 36 C). Gastropods (13.40%) formed and important diet component in C. digrammus while common food items consisted of starfish remains, stomatopods, pelecypods and lobster remains forming proportions of 4.00, 3.40, 2.00 and 1.60% respectively (Fig. 36 D). In C. trilobatus, crabs, gastropods and sea urchin remains

formed important gut contents (14.30, 13.60 & 10.70% respectively) while fish, stomatopods and lobster remains were commonly encountered (5.60, 5.29 & 3.21% respectively). Remains of sipunculids and starfish were rare (Fig. 36 E). Cheilinus undulatus fed predominantly on crabs (40.00%) and gastropods (23.70%). Remains of starfish and sea urchins were commonly encountered (7.22 & 6.60% respectively). Alpheids (3.90%) and crustacean remains (2.00%) were occasionally recorded. Fish, pelecypods and stomatopods were rare (Fig. 36 F).

Mainly crustacean remains (30.00%) shrimp (17.20%) and gastropods (14.70%) formed the food items of Chelio inermis, while crabs (10.70%) were common in the diets, alpheids (5.70%). Fish (1.80%), sipunculid remains (1.30%) and stomatopods (1.00%) were occasionally recorded. Eggs and pelecypods were rare (Fig. 36 G). Coris formosa fed predominantly on gastropods (30.40%) followed by sea urchin remains (20.80%) and crabs (17.50%). Alpheids (10.00%) and starfish remains (7.80%) were common, while pelecypods (1.60%) were consumed occasionally. Stomatopods were rare (Fig. 37 A). C. gaimard indicated a wider food niche as compared to C. formosa mainly preferring sea urchin remains (27.63%), crabs (19.17%) and starfish remains (14.00%). Gastropods and stomatopods were also common forming proportions of 10.60 and 8.90% respectively. Remains of lobsters, crustaceans and fish (4.80, 3.30 and 3.00% respectively) were common while pelecypods were rare (Fig. 37 B).

Gomphosus coeruleus and G. varius preferred shrimps in their diets (20.60 & 43.70% respectively). G. coeruleus also fed predominantly on remains of starfish (19.90%) and sea urchins (15.90%). Remains of crustaceans and lobsters, crabs and alpheids formed other common food items (4.80, 1.60, 3.77 & 3.63% respectively). Apart from shrimp as a major gut content in G. varius, stomatopods (11.40%) were commonly fed upon. Remains of starfish (3.20%) were occasionally recorded. Fish and alpheids were rare (Fig. 37 C, D).

Halichoeres centiquadrus fed mainly on gastropods (60.80%) followed by crabs (16.70%). Pelecypods and polychaetes (3.60 and 1.60% respectively) were common while stomatopods were rare (Fig. 37 E). Crabs and gastropods formed major diet components of H. marginatus accounting for 46.80 and 15.40% of food items recorded. Alpheids, shrimp and stomatopods (6.00, 5.00 & 3.20% respectively) were commonly consumed, while pelecypods (1.60%) were occasionally recorded (Fig. 37 F). Gastropods, pelecypods, crabs and alpheids were common food items in H. nebulosus (31.60, 1.20, 30.00 & 4.60% respectively) and in H. scapularis (22.30, 3.30, 19.40 & 2.40% respectively). H. nebulosus occasionally consumed shrimp (2.30%), stomatopods (1.89%), sea urchin remains (1.10% and polychaetes (1.00%). (Fig. 37 G). Sea urchins (16.30%) formed an important constituent in the diet of H. scapularis apart from commonly occurring food items,

namely, starfish remains, polychaetes, and shrimp that formed proportions of 5.82, 4.40 and 1.40% respectively. Sipunculid remains were rare (Fig. 37 H).

Crabs and sea urchin remains dominated the gut contents of Hemigymnus melapterus and H. fasciatus forming proportions of 21.25, 16.60% and 21.60, 12.10% respectively. H. melapterus preferred stomatopods (14.30%) and gastropods (7.10%) apart from other common food items, namely, alpheids, fish and lobster remains that formed proportions of 4.43, 3.92 and 3.40% respectively (Fig 38 A). H. fasciatus commonly fed upon fish and stomatopods (10.30 and 8.90% respectively). Gastropods (3.80%) were commonly encountered in gut contents while lobster remains were rare (Fig. 38 B). Hologymnosus doliatus was found to feed on relatively few food items of which fish (66.50%) was dominant, followed by shrimp (14.50%). Alpheids and eggs formed proportions of 2.40 and 1.20% respectively (Fig 38 C).

Labroides bicolor and L. dimidiatus showed similar food preferences (Fig. 38 D & E). Crustacean remains and shrimp dominated stomach contents in the two species forming proportions of 33.00, 10.30% and 26.00, 14.80% respectively. Polychaetes (3.60%) were common in diets of L. dimidiatus while in L. bicolor they were rare (0.10%). Eggs (6.00%) were commonly consumed by L. bicolor. Crabs (40.70%) and alpheids (21.90%) were dominant food items of Novaculichthys taeniourus. Lobster remains (9.90%),

sea urchin (5.00%), starfish remains (5.00%) and stomatopods (3.80%) were commonly recorded. Crustacean remains (1.00) occurred occasionally (Fig 39 A).

Stethojulis albovittata fed predominantly on gastropods (55.20%) followed by shrimp (14.80%). Crustacean remains, crabs and polychaetes formed proportions of 8.70, 3.00 and 3.00% respectively (Fig 39 B). Gastropods (40.30%) and shrimp (17.20%) formed dominant food items in S. interrupta. Crabs and pelecypods were commonly recorded with proportions of 8.60 and 3.00% respectively. Polychaetes (1.20%) were recorded occasionally (Fig 39 C). S. strigiventer fed predominantly on shrimp (30.00%) followed by gastropods (13.09%) and crabs (10.50%). Alpheids (6.70%) were commonly recorded while fish were rare (Fig 39 D).

Thalassoma hardwicki preferred crabs (20.40%) and gastropods (25.00%). Alpheids, starfish remains, stomatopods and lobster remains formed proportions of 10.60, 4.60, 3.56 and 1.80% respectively. Occurrence of pelecypods was rare (Fig 39 E). Gastropods (36.71%) formed the dominant food item in T. herbraicum, Fish and sea urchin remains were common with proportions of 7.70 and 5.30% respectively. Stomatopods, starfish, pelecypods and crabs formed occasional food items accounting for 3.30, 2.89, 1.80 and 1.80% of gut contents (Fig 39 F). Thalassoma lunare fed mainly on eggs (23.25%), polychaetes (16.80%) and fish (12.60%). Gastropods and crabs formed common food items with

proportions of 6.60 and 2.33% respectively (Fig 39 G). Gastropods (30.70%) and shrimp (14.83%) formed dominant food items of T. purpureum. Alpheids and crabs (8.90 and 8.87% respectively) were commonly recorded while pelecypods and sea urchins (3.60% each) were occasionally consumed. Lobster remains were rare (Fig 39 H). Semidigested matter constituted 7 to 56% of the gut contents, mainly containing hard parts of various food items.

Feeding diversity (H') of each labrid species is given in Fig 40. Of these, 20 species recorded H' values above 2.00. Coris gaimard indicated the highest diversity of 2.88, followed by Cheilio inermis (2.72). H' values of Anampses caerulopunctatus (2.40) and Navaculichthys taeniourus (2.41) were comparable. Four species belonging to genus Cheilinus had H' values ranging between 2.10 and 2.36 except C. digrammus that showed a feeding diversity of 1.87. Coris formosa had H' of 2.52. Gomphosus coeruleus (2.53) indicated a higher diversity as compared to G. varius (1.66). The four species belonging to genus Halichoeres recorded H' values between 2.13 and 2.71 except in H. centiquadrus where a H' of 1.62 was observed.

Hemigymnus melapterus and H. fasciatus recorded H' values of 2.64 and 2.26 respectively. Labroides bicolor and L. dimidiatus indicated relatively low H' values (1.62 and 1.56 respectively). Among the three species of the genus Stethojulis, S. albovittata had the least feeding diversity of 1.90 while S. interrupta and S. strigiventer indicated higher H' values of 2.02 and 2.09

Table 34. Percentage occurrence of food items in the guts of twentyeight labrids, (Number of fishes (N), size ranges in mm, feeding diversity - H').

	SPECIES			FOOD ITEMS															
TABLE 34	LABRIDAE	N	SIZE RANGE (mm)	GASTR	PELCY	CRAB	ALPHE	CRUS.R	LOBS.R	S.URCH	STOMAP	POLYCH	SIPUN	SRIMP	STAR.R	EGGS	FISH	SDM	H'
1.	Anampses caeruleopunctatus	19	93 - 149	11.80	3.00	42.90	16.90	-	3.80	-	2.88	-	-	-	5.60	-	-	13.12	2.40
2.	Bodianus axillaris	4	152 - 157	-	-	-	-	6.70	-	-	-	-	-	-	-	-	60.00	33.30	1.23
3.	Cheilinus chlorurus	16	88 - 200	20.20	-	33.30	-	-	-	3.01	5.00	-	-	0.10	1.40	-	1.60	35.39	2.10
4.	C. digrammus	11	123 - 233	13.40	2.00	56.80	-	-	1.60	-	3.40	-	-	-	4.00	-	-	18.80	1.87
5.	C. trilobatus	23	129 - 200	13.60	-	14.30	-	-	3.21	10.70	5.29	-	0.50	-	0.50	-	5.60	46.30	2.34
6.	C. undulatus	20	145 - 193	23.70	0.70	40.00	3.90	2.00	-	6.60	0.10	-	-	-	7.22	-	0.78	15.00	2.36
7.	Cheilio inermis	30	100 - 320	14.70	0.59	10.70	5.70	30.00	-	-	1.00	-	1.30	17.20	-	0.61	1.80	16.40	2.72
8.	Coris formosa	15	270 - 410	30.40	1.60	17.50	10.00	-	-	20.80	0.10	-	-	-	7.80	-	-	11.80	2.52
9.	C. gaimard	20	300 - 410	10.60	0.70	19.17	-	3.30	4.80	27.63	8.90	-	-	-	14.00	-	3.00	7.90	2.88
10.	Gomphosus coeruleus	27	125 - 180	-	-	3.77	3.63	4.80	1.60	15.90	-	-	-	20.60	19.90	-	-	29.80	2.53
11.	G. varius	12	55 - 122	-	-	-	0.44	-	-	-	11.40	-	-	43.70	3.20	-	0.80	40.46	1.66
12.	Halichoeres centiquadrus	120	25 - 220	60.80	3.60	16.70	-	-	-	-	0.70	1.60	-	-	-	-	-	16.60	1.62
13.	H. marginatus	28	95 - 163	15.40	1.60	46.80	6.00	-	-	-	3.20	-	-	5.00	-	-	-	22.00	2.13
14.	H. nebulosus	35	47 - 100	31.60	1.20	30.00	4.60	-	-	1.10	1.89	1.00	-	2.30	-	-	-	26.31	2.22
15.	H. scapularis	126	40 - 182	22.30	3.30	19.40	2.40	-	-	16.30	-	4.40	0.20	1.40	5.82	-	-	24.48	2.71
16.	Hemigymnus melapemis	12	142 - 159	7.10	-	21.25	4.43	-	3.40	16.60	14.30	-	-	-	-	-	3.92	29.00	2.64
17.	H. fasciatus	10	152 - 160	3.80	-	21.60	-	-	0.80	12.10	8.90	-	-	-	-	-	10.30	42.50	2.26
18.	Hologymnosus doliatus	8	200 - 219	-	-	-	2.40	-	-	-	-	-	-	14.50	-	1.20	66.50	15.40	1.42
19.	Labroides bicolor	4	100 - 120	-	-	-	-	33.00	-	-	-	0.10	-	10.30	-	6.00	-	50.60	1.62
20.	L. dimidiatus	38	30 - 82	-	-	-	-	26.00	-	-	-	3.60	-	14.80	-	-	-	55.60	1.56
21.	Novaculichthys taeniourus	25	156 - 230	-	-	40.70	21.90	1.00	9.90	5.00	3.80	-	-	-	5.00	-	-	12.70	2.41
22.	Stethojulis albovittata	56	37 - 90	55.20	-	3.00	-	8.70	-	-	-	3.00	-	14.80	-	-	-	15.30	1.90
23.	S. interrupta	79	40 - 115	40.30	3.00	8.60	-	-	-	-	-	1.20	-	17.20	-	-	-	29.70	2.02
24.	S. strigiventer	39	45 - 120	13.09	-	10.50	6.70	-	-	-	-	-	-	30.00	-	-	0.80	38.91	2.09
25.	Thalassoma hardwicki	73	90 - 154	25.00	0.94	30.40	10.60	-	1.80	-	3.56	-	-	-	4.60	-	-	28.10	2.38
26.	T. herbraicum	12	105 - 230	36.71	1.80	1.80				5.30	3.30		-	-	2.89	-	7.70	40.50	2.07
27.	T. lunare	51	125 - 170	6.60	-	2.33	-	-	-	-	-	16.80	-	-	-	23.25	12.60	38.42	2.22
28.	T. purpureum	8	160 - 213	30.70	3.60	8.87	8.90	-	0.50	3.60	-	-	-	14.83	-	-	-	29.00	2.45

ALPHE - alpheid shrimp, CRAB - crabs, CRUS.R - crustacean remains, EGGS - eggs, FISH - fish, GASTR - gastropods, LOBS.R - Lobster remains, PELCY - pelecypods, POLYCH - polychaetes, STAR.R - starfish remains, SIPUN - sipunculids, SRIMP - shrimp, SDM - semidigested matter.

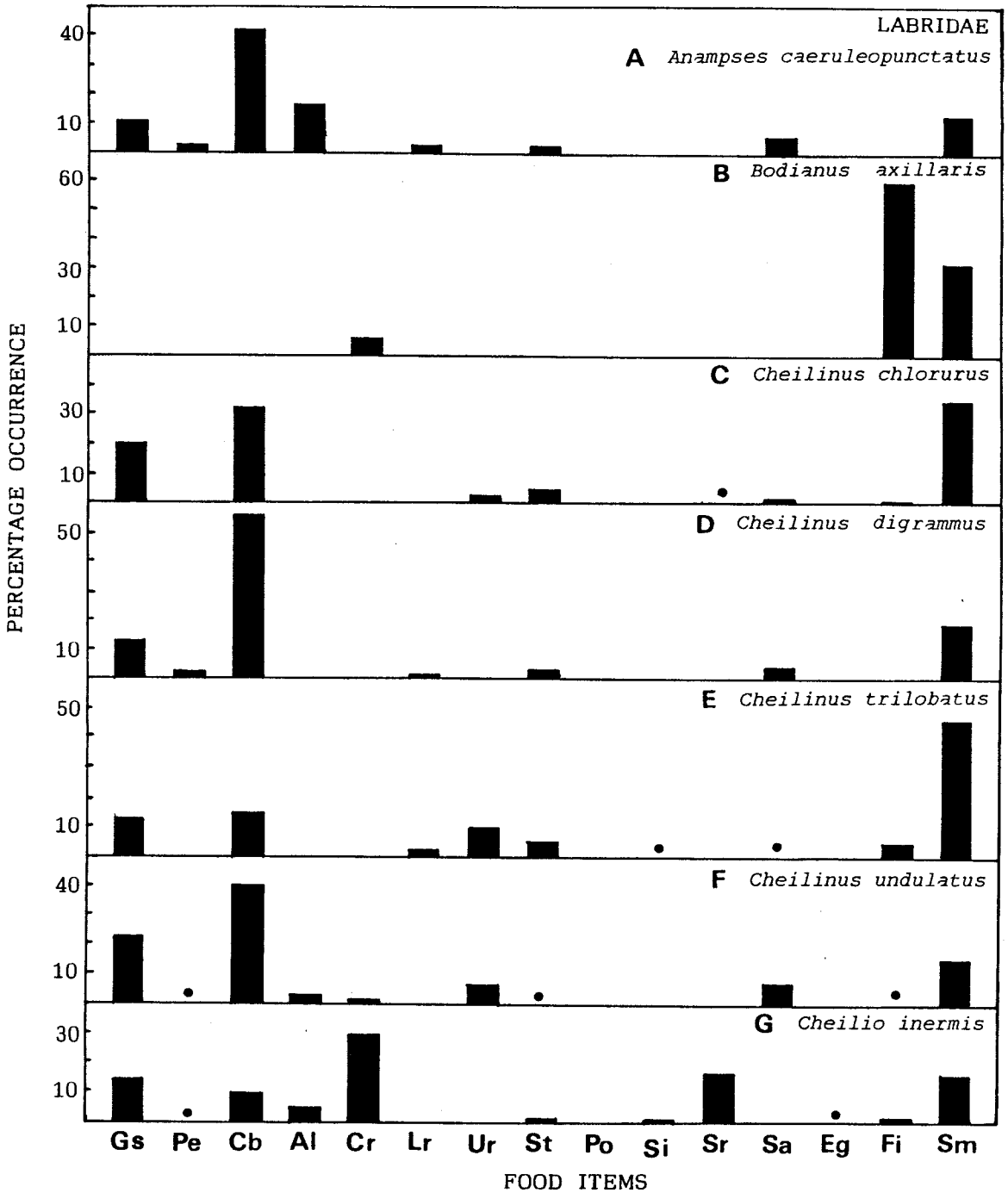

Figure 36. Percentage occurrence of food items in the guts of seven labrid (A to G) species.

(Gs - gastropods, Pe - pelecypods, Cb - crabs, Al - alpheid shrimp, Cr - crustacean remains, Lr - lobster remains, Ur - sea urchin remains, St - stomatopods, Po - polychaetes, Si - sipunculids, Sr - shrimp, Sa - starfish remains, Eg - eggs, Fi - fish, Sm-semidigested matter) • less than 0.5%.

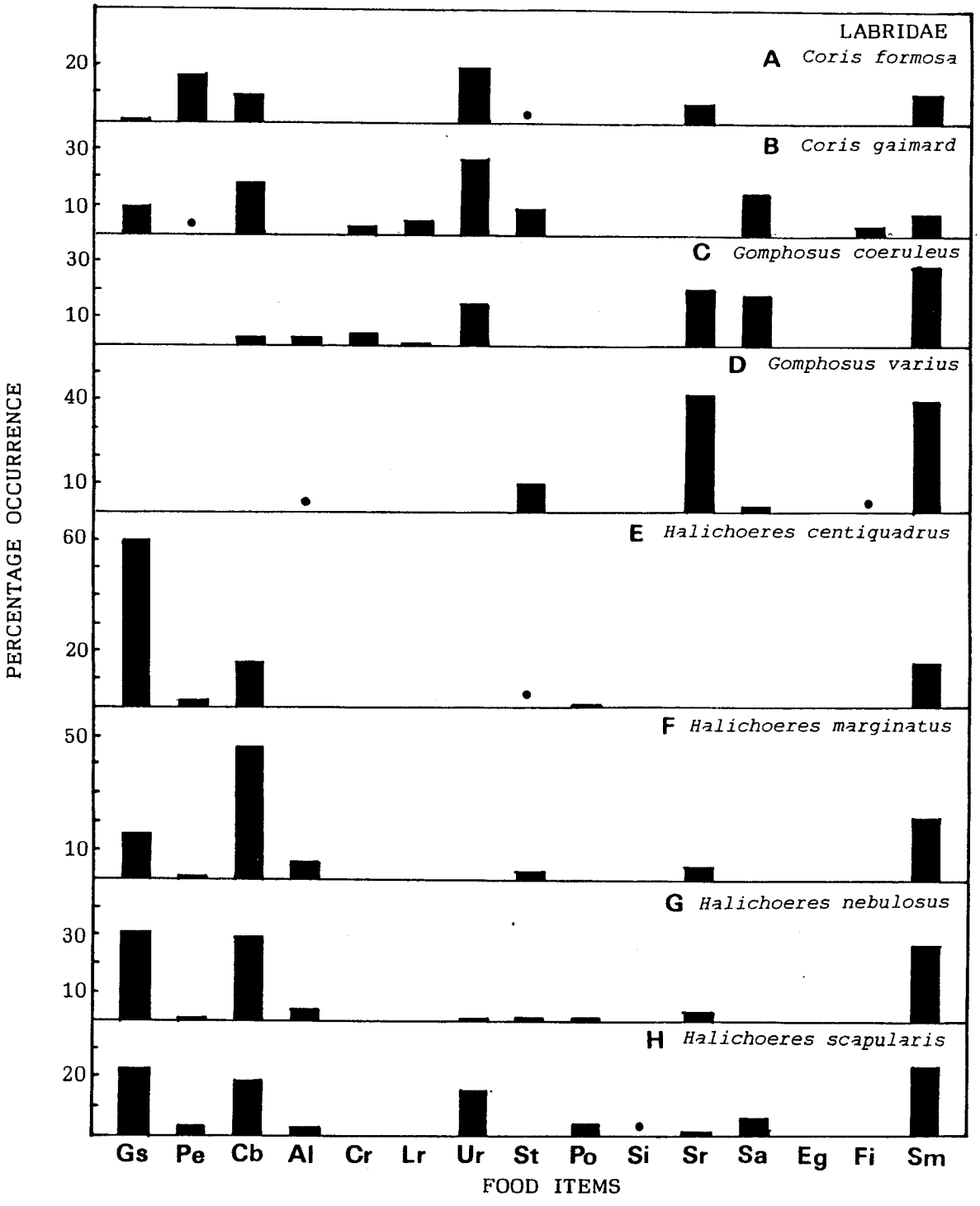

Figure 37. Percentage occurrence of food items in the guts of eight labrid (A to H) species.

(Gs - gastropods, Pe - pelecypods, Cb - crabs, Al - alpheid shrimp, Cr - crustacean remains, Lr - lobster remains, Ur - sea urchin remains, St - stomatopods, Po - polychaetes, Si - sipunculids, Sr - shrimp, Sa - starfish remains, Eg - eggs, Fi - fish, Sm - semidigested matter) • less than 0.5%.

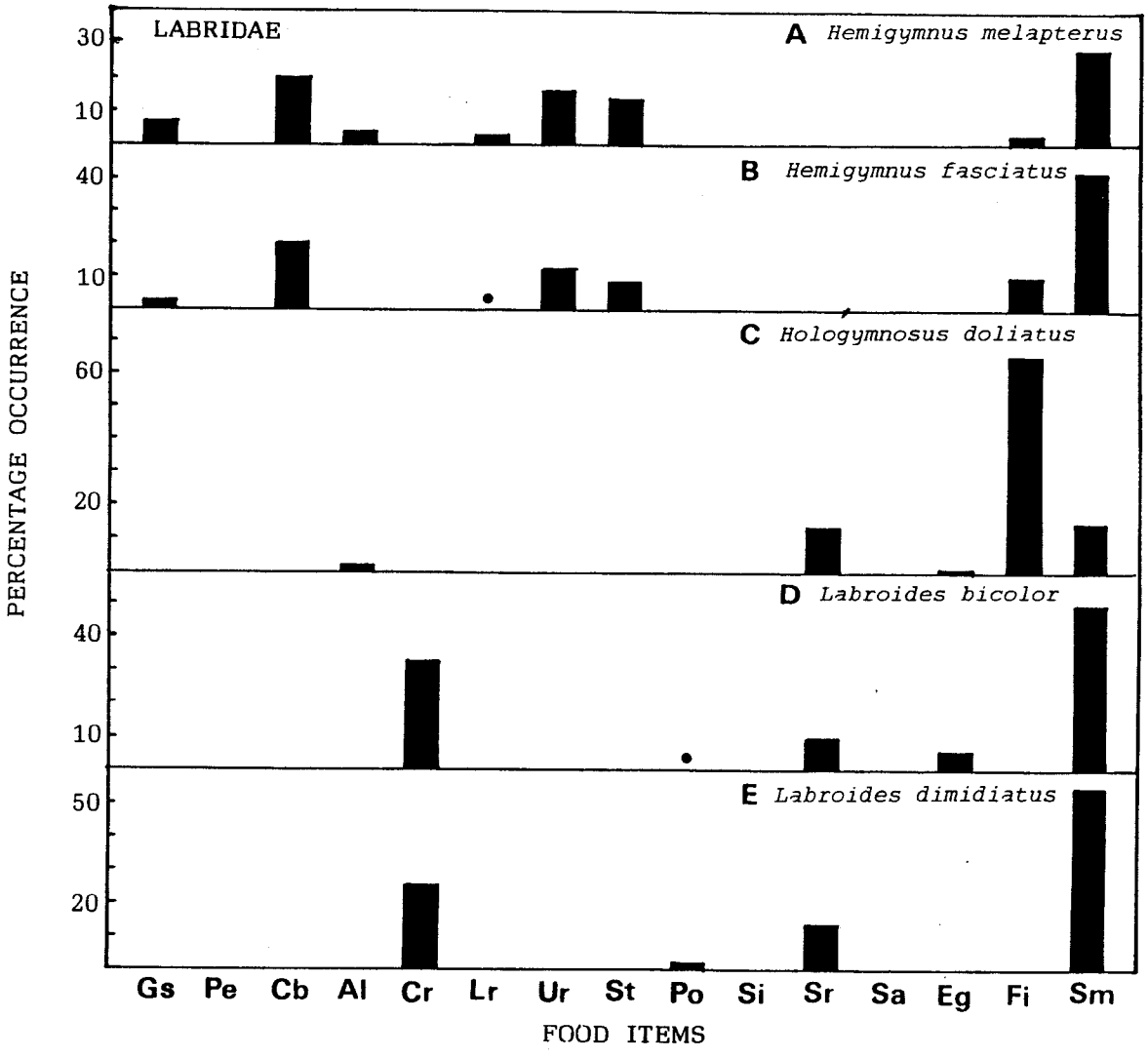

Figure 38. Percentage occurrence of food items in the guts of five labrid (A to E) species.

(Gs - gastropods, Pe - pelecypods, Cb - crabs, Al - alpheid shrimp, Cr - crustacean remains, Lr - lobster remains, Ur - sea urchin remains, St - stomatopods, Po - polychaetes, Si - sipunculids, Sr - shrimp, Sa - starfish remains, Eg - eggs, Fi - fish, Sm - semidigested matter) • less than 0.5%.

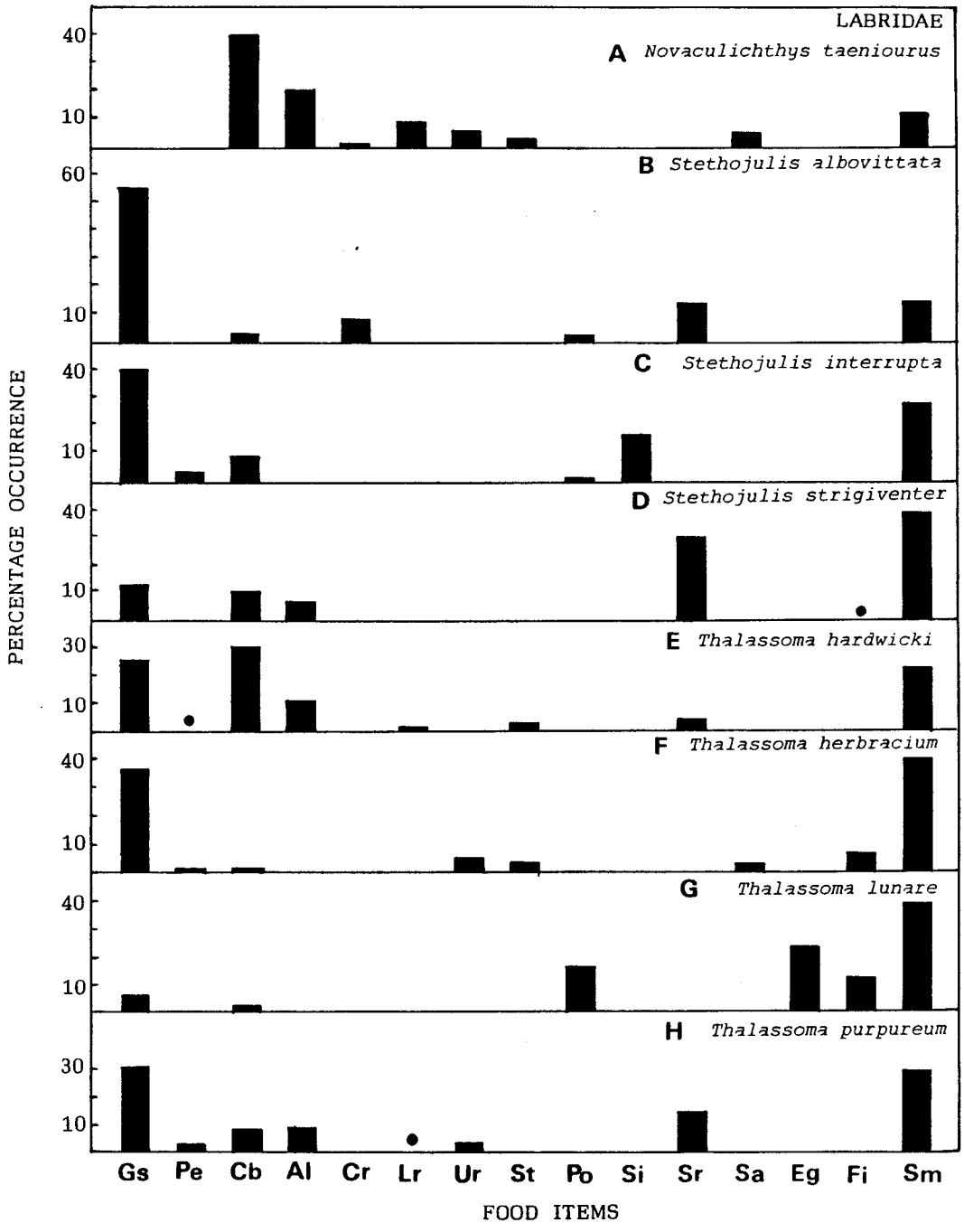

Figure 39. Percentage occurrence of food items in the gut of eight labrid (A to H) species.

(Gs - gastropods, Pe - pelecypods, Cb - crabs, Al - alpheid shrimp, Cr - crustacean remains, Lr - lobster remains, Ur - sea urchin remains, St - stomatopods, Po - polychaetes, Si - sipunculids, Sr - shrimp, Sa - starfish remains, Eg - eggs, Fi - fish, Sm - semidigested matter) • less than 0.5%.

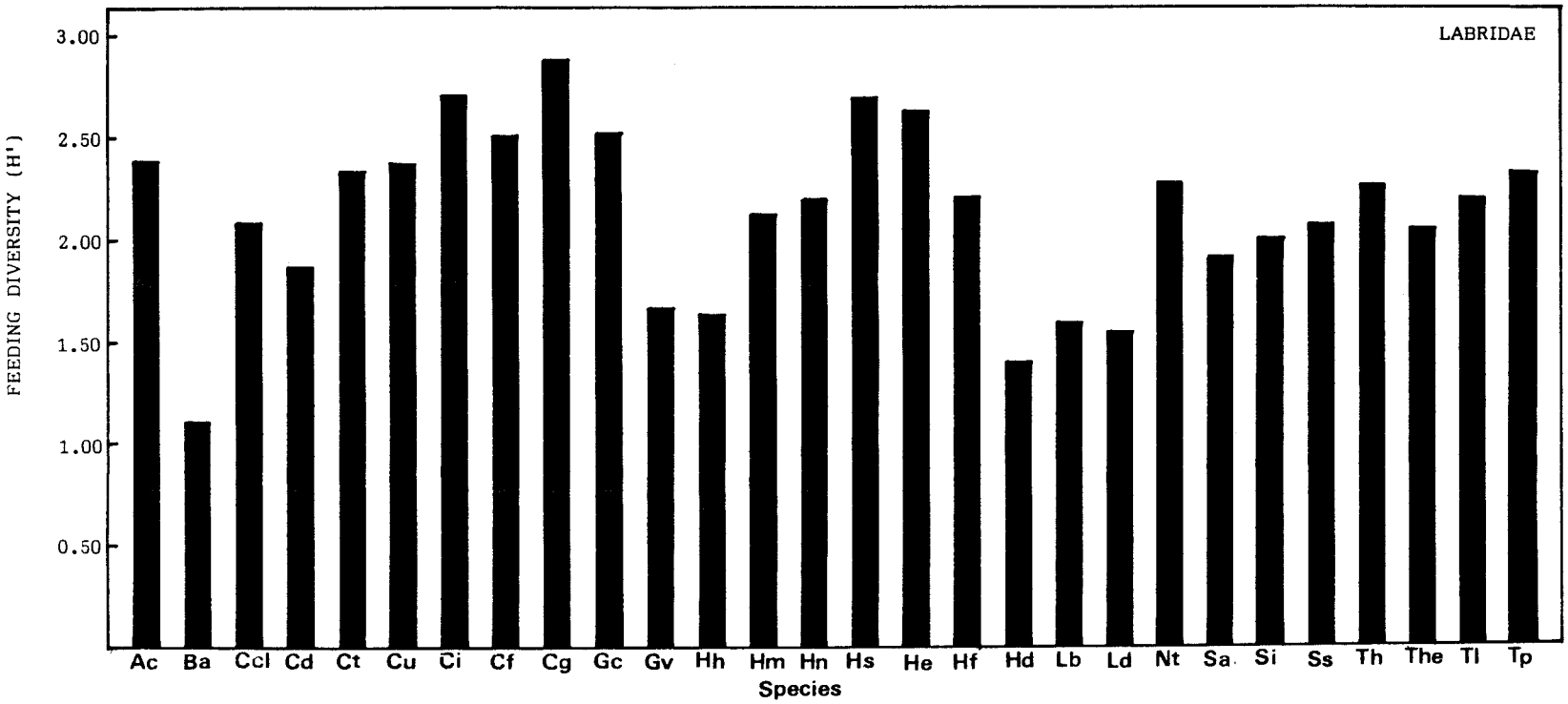

Figure 40. Feeding diversity (H') of twentyeight labrid species.

(Ac - Anampses caeruleopunctatus, Ba - Bodianus axillaris, Ccl - Cheilinus chlorurus, Cd - C. digrammus, Ct - C. trilobatus, Cu - C. undulatus, Ci - Cheilo inermis, Cf - Coris formosa, Cg - C. gaimard, Gc - Gomphosus coeruleus, Gv - G. varius, Hc - Halichoeres centiquadrus, Hm - H. marginatus, Hn - H. nebulosus, Hs - H. scapularis, He - Hemigymnus melapterus, Hf - H. fasciatus, Hd - Hologymnosus doliatus, Lb - Labroides bicolor, Ld - L. dimidiatus, Nt - Novaculichthys taeniourus, Sa - Stethojulis albovittata, Si - S. interrupta, Ss - S. strigiventer, Th - Thalassoma hardwicki, The - T. herbraicum, Tl - T. lunare, Tp - T. purpureum).

respectively. The four species of the genus Thalassoma had H' values between 2.09 and 2.45. Bodianus axillaris and Hologymnosus doliatus indicated the least H' values (1.23 & 1.42 respectively).

15. Lethrinidae: Food preferences and feeding diversity (H') of four species of lethrinids are given in Table 35. Gnathodentex aureolineatus mainly fed on polychaetes (63.40%) while crabs and shrimp formed and 8.33 and 8.01% of stomach contents respectively (Fig 41 M). Crabs formed the major food item in Lethrinus ornatus, L. xanthochilus and Monotaxis grandoculis with varying proportions (48.10, 50.17 & 68.21% respectively). L. ornatus also fed on shrimp (14.20%) while fish (6.30%) formed an occasional diet. Sipunculid remains were rare (Fig 41 N). Apart from feeding on crab, L. xanthochilus consumed shrimps and polychaetes forming proportions of 4.05 and 2.36% respectively (Fig 41 O). Pelecypods (18.50%) were important constituents in the stomachs of M. grandoculis. Polychaetes (6.77%) and gastropods (6.36%) were commonly recorded while starfish were rare (Fig 41 P). While no semidigested matter was recorded in M. grandoculis, it ranged between 20.00 and 44.00% in other species.

Feeding diversity (H') of the four lethrinids was below 2.00. Among these, L. ornatus indicated a diversity of 1.72 while relatively low diversities were observed in L. xanthochilus and M. grandoculis (1.34 & 1.35 respectively). Gnathodentex aureolineatus recorded a H' value of 1.48.

16. Lutjanidae: Food preferences and feeding diversities of four lutjanid species are given in Table 36. Only fish (63.00%) was found in the stomach contents of Aprion virescens (Fig 41 I). Fish (51.66%), crabs (28.55%) and shrimp (11.39%) were important in stomach constituents in Lutjanus bohar. Sipunculid remains (5.72%) were commonly recorded (Fig. 41 J). Crabs and fish were preferred by L. gibbus and L. kasmira with proportions of 60.19, 27.13% and 41.57, 22.88% respectively. Shrimp was a rare food item of L. gibbus (Fig 41 K). L. kasmira preferred shrimp (26.67%) while polychaetes (3.68%) were occasionally recorded (Fig 41 L). Semidigested matter varied between 2.00 and 37.00%.

Feeding diversity in Aprion virescens was low (0.95) while the same in L. bohar, L. gibbus and L. kasmira was 1.75, 1.86 and 1.93 respectively.

17. Malacanthidae: Three individuals of Malacanthus latovittatus in the size range of 350 to 370 mm were examined. They mainly fed on fish (15.10%) and polychaetes (12.00%). Green algae and polychaete egg mass formed proportions of 6.30 and 3.50%. Semidigested matter formed 63.10% of the stomach content (Fig 41 A). M. latovittatus recorded a feeding diversity of 1.62.

18. Mugilidae: 12 individuals of Crenemugil crenilabis in the size range of 73 to 156 mm were examined. Green algae (43.80%), amphipods (13.10%) and polychaetes (12.50%) formed important stomach constituents. Semidigested matter formed 30.60% (Fig. 42 A). C. crenilabis recorded a feeding diversity of 1.80.

19. Mugiloididae: 18 individuals of Parapercis hexophthalma in the size range of 93 to 210 mm were examined. They fed mainly on fish (56.00%) while crabs (6.00%) were occassionally recorded. Cephalopods and polychaetes occasionally occurred forming 2.00 and 1.59% of the stomach contents. 34.41% of stomach content was semidigested matter (Fig 42 B).

20. Mullidae: Food preferences and feeding diversity (H') of six species of mullids are given in Table 37. Crabs (37.10%) and shrimp (28.12%) formed dominant food items of Mulloides flavolineatus. Polychaetes and sipunculid remains formed proportions of 16.16 and 7.46% while amphipods (2.55%) were occasionally present among stomach contents. Pelecypods were rare (Fig 41 C). Parupeneus barberinus mainly fed on polychaetes (52.14%) and crabs (23.43%). Shrimp (9.61%) was common in its diet, while gastropods and amphipods (2.55 & 1.17%) were occasionally recorded. Fish was rare (Fig 41 D). P. bifasciatus preferred crabs (47.08%) and shrimp (21.56%). Polychaetes were common food items (12.26%), while fish and gastropods formed proportions of 2.50 and 2.30 respectively (Fig 41 E). Fish (56.15%) formed the dominant food item in P. cyclostomus followed by crabs (30.18%). Polychaetes and cephalopods formed proportions of 7.92 and 5.80% respectively (Fig 41 F). P. macronema preferred shrimp and crabs that formed proportions of 39.05 and 35.23% respectively, followed by polychaetes (15.09%). Fish was a common food item forming 6.44% of stomach contents

while amphipods were rare (Fig 41 G). Crabs and polychaetes (40.16 & 24.32% respectively) followed by shrimps and pelecypods (16.15 & 13.64% respectively) formed the dominant food of P. pleurostigma. Sea urchin remains and amphipods were rare. (Fig 41 H). Semidigested matter was not recorded in P. cyclostomus while in others it was between 4.00 and 15.00%.

Feeding diversity values of the six mullids are given in Fig 43 A. Mulloides flavolineatus, Parupeneus pleurostigma and P. bifasciatus indicated high H' values of 2.18, 2.12 and 2.02 respectively. H' in the other species ranged between 1.52 and 1.93, the least (1.52) in P. cyclostomus.

21. Plesiopidae: 24 individuals of Plesiops caeruleolineatus in the size range of 40 to 86 mm were examined. Crabs (36.14%) dominated the stomach contents while polychaetes, amphipods, isopods and fish formed proportions of 15.40, 12.00, 10.00 and 6.30% respectively. Semidigested matter constituted 20.16% (Fig 42 H). P. caeruleolineatus recorded a feeding diversity of 2.37.

22. Pomacanthidae: 20 individuals of Centropyge multispinis in the size range of 115 to 126 mm were examined. Copepods (40.26%) and decapod larvae (27.00%) were dominant food items. Crabs, fish and filamentous algae formed proportions of 11.00, 10.22 and 6.80% respectively. Semidigested matter formed 4.72% (Fig 42 I).

Tables 35, 36 & 37. Percentage occurrence of food items in the guts of various species belonging to Lethrinidae, Lutjanidae and Mullidae. (Number of fishes (N), size ranges in mm, feeding diversity - H').

SPECIES		FOOD ITEMS											
TABLE 35	LETHRINIDAE	N	SIZE RANGE (mm)	CRAB	FISH	POLYCH	SIPUN	SRIMP	PELCY	GASTR	STAR.R	SDM	H'
1.	Gnathodentex aureolineatus	98	90 - 193	8.33	-	63.40	-	8.01	-	-	-	20.26	1.48
2.	Lethrinus ornatus	27	123 - 230	48.10	6.30	-	0.52	14.20	-	-	-	30.88	1.72
3.	L. xanthochilus	12	83 - 335	50.17	-	2.36	-	4.05	-	-	-	43.42	1.34
4.	Monotaxis grandoculis	7	170 - 294	68.21	-	6.77	-	-	18.50	6.36	0.16	-	1.35

TABLE 36	LUTJANIDAE	N	SIZE RANGE (mm)	FISH	CRAB	SIPUN	POLYCH	SRIMP	SDM	H'
1.	Aprion virescens	3	490 - 500	63.00	-	-	-	-	37.00	0.95
2.	Lutjanus bohar	23	260 - 326	51.66	28.55	5.72	-	11.39	2.68	1.75
3.	L. gibbus	64	140 - 345	27.13	60.19	12.50	-	0.18	27.13	1.86
4.	L. kasmira	76	30 - 165	22.88	41.57	-	3.68	26.67	5.20	1.93

TABLE 37	MULLIDAE	N	SIZE RANGE (mm)	CRAB	POLYCH	SIPUN	SRIMP	AMPHI	GASTR	PELCY	FISH	CEPHA	S.URCH	SDM	H'
1.	Mulloides flavolineatus	168	63 - 270	37.10	16.16	7.46	28.12	2.55	-	0.15		-	-	8.46	2.18
2.	Parupeneus barberinus	89	39 - 218	23.43	52.14	-	9.61	1.17	2.55	-	0.10	-	-	11.00	1.87
3.	P. bifasciatus	63	60 - 190	47.08	12.26	-	21.56	-	2.30	-	2.50	-	-	14.30	2.02
4.	P. cyclostomus	4	133 - 152		7.92	-	30.13	-	-	-	56.15	5.80	-	-	1.52
5.	P. macronema	67	55 - 196	35.23	15.09	-	39.05	0.19	-	-	6.44	-	-	4.00	1.93
6.	P. pleurostigma	54	42 - 170	40.16	24.31	-	16.15	0.30	-	13.64	-	-	0.34	5.10	2.12

AMPHI - amphipods, CRAB - crabs, CEPHA - cephalopods, FISH - fish, GASTR - gastropods, PELCY - pelecypods, POLYCH - polychaetes, SIPUN - sipunculids, SRIMP - shrimp, STAR.R - starfish remains, S.URCH - sea urchin remains, SDM - semidigested matter.

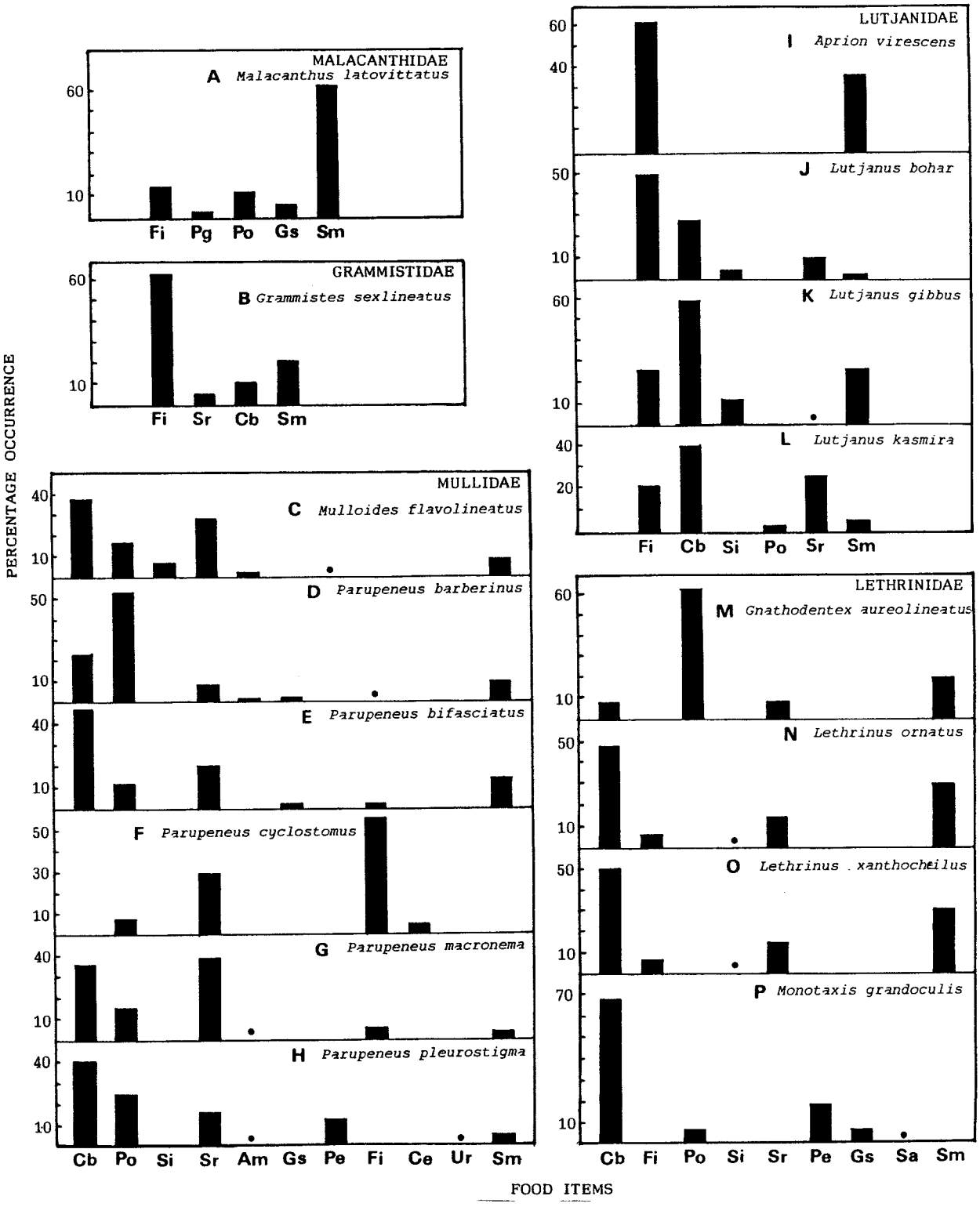

Figure 41. Percentage occurrence of food items in the guts of various species belonging to families Malacanthidae, Grammistidae, Mullidae, Lutjanidae and Lethrinidae. (A to P)

(Am - amphipods, Cb - crabs, Ce - cephalopods, Fi - fish, Gs - gastropods, Pe - pelecypods, Pg - Polychaete egg mass, Po - polychaetes, Sa - starfish remains, Si - sipunculids, Sr - shrimp, Ur - seaurchin remains, sm - semidigested matter)

• less than 0.5%.

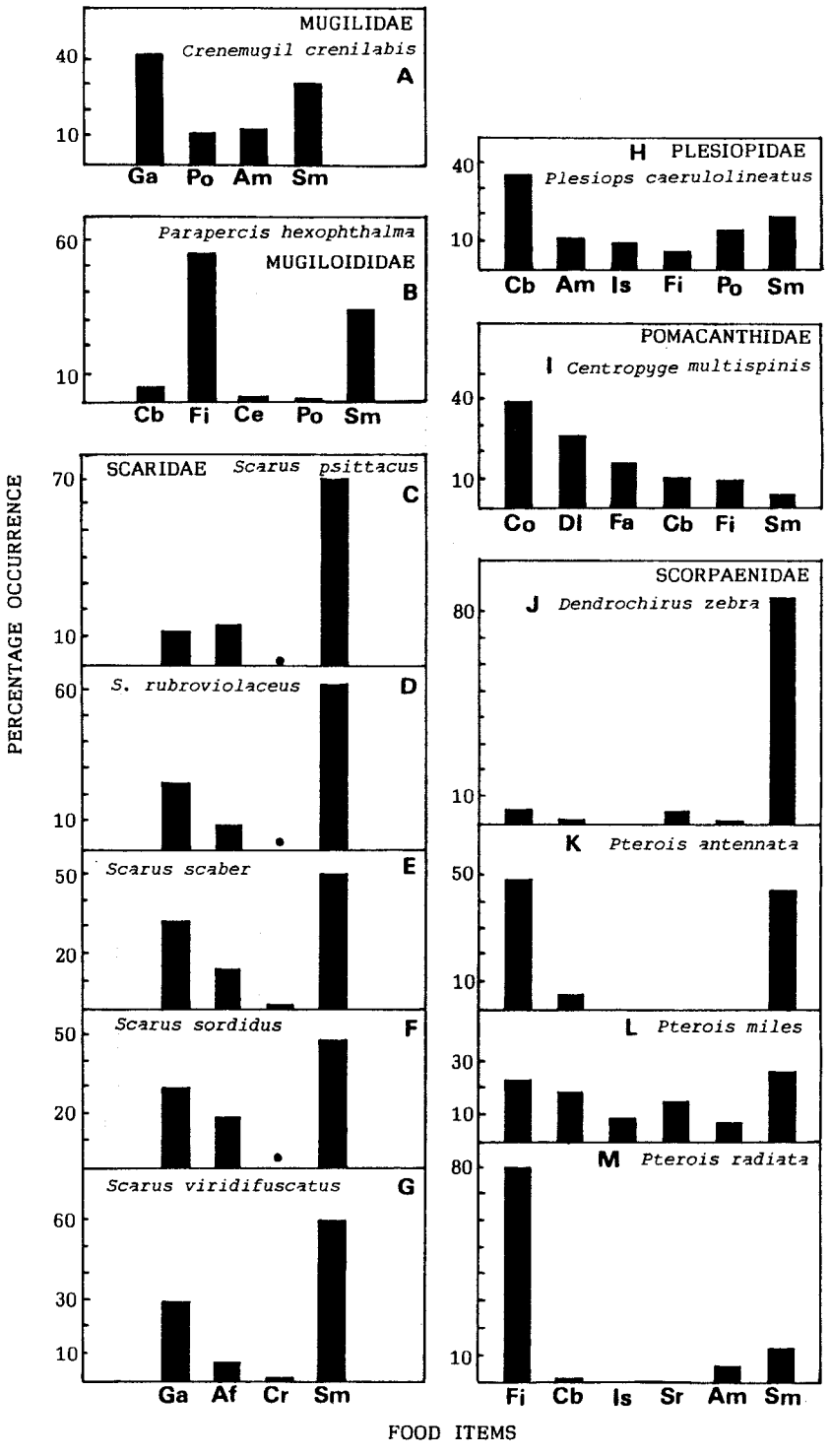

Figure 42. (A to M) Percentage occurrence of food items in the guts of various species belonging to families, Mugilididae, Mugiloididae, Scaridae, Plesiopidae, Pomacanthidae and Scorpaenidae.

(Af - algal fragments, Am - amphipods, Cb - crabs, Ce - cephalopods, Co - copepods, Cr - Crustacean remains, Dl - decapod larvae, Fa - filamentous algae, Fi - fish, Ga - green algae, Is - isopods, Po - polychaetes, Sr - shrimp, Sm - semidigested matter) • less than 0.5%.

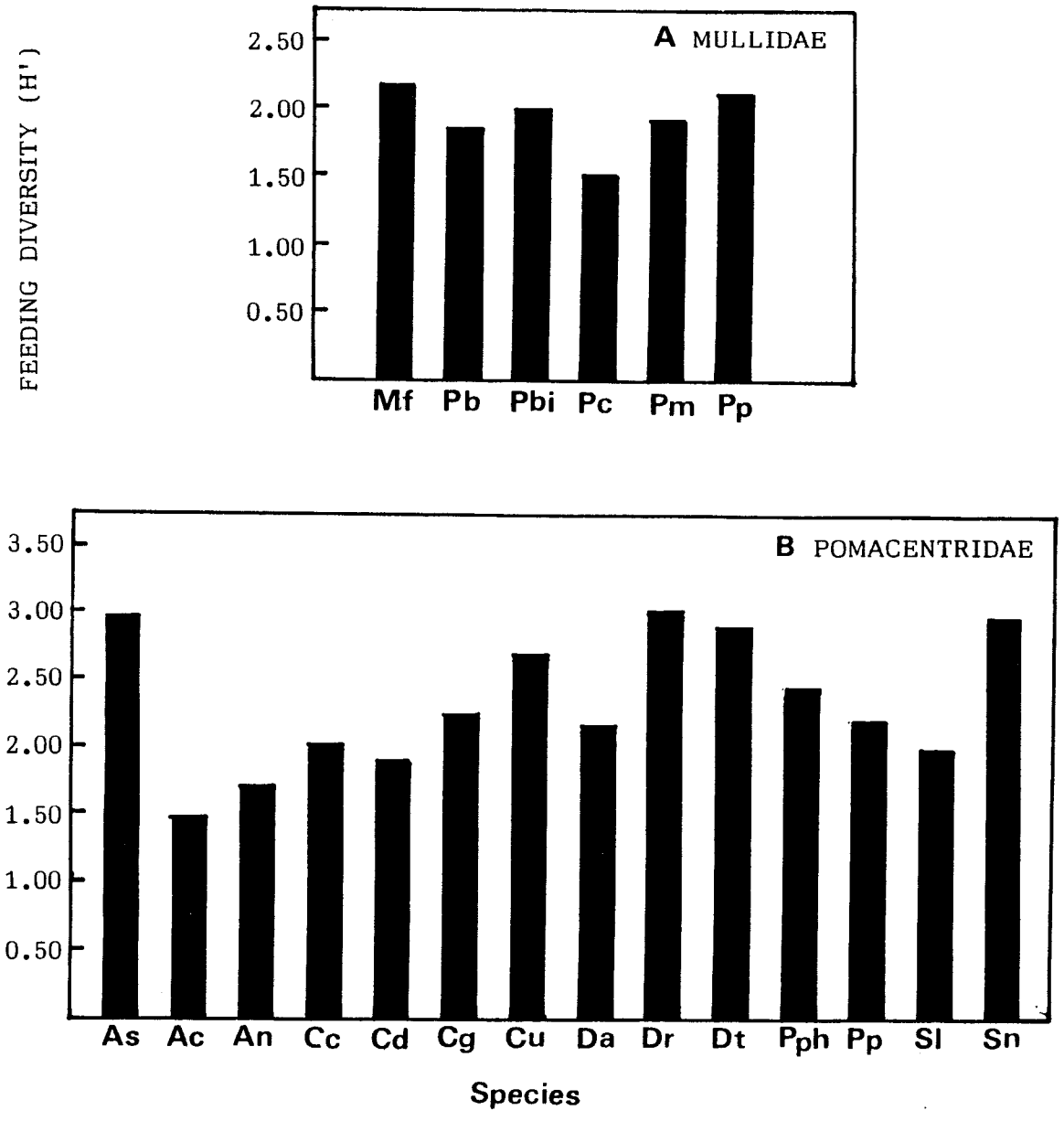

Figure 43. Feeding diversity (H') of various species belonging to Mullidae (A) and Pomacentridae (B).

(Mf - Mulloides flavolineatus, Pb - Parupeneus barberinus, Pbi - P. bifasciatus, Pc - P. cyclostomus, Pm - P. macronema, Ph - P. pleurostigma; As - Abudefduf sexfasciatus, Ac - Amphiprion nigripes, Cc - Chromis caerulea, Cd - C. dimidiata, Cg - Chrysiptera glauca, Cu - C. unimaculata, Da - Dascyllus aruanus, Dt - D. trimaculatus, Pph - Plectroglyphidodon phoenixensis, Pp - Pomacentrus pavo, Sl - Stegastes lividus, Sn - S. nigricans).

23. Pomacentridae: Food preferences and feeding diversities of 14 species of pomacentrids are given in Table 38. Shrimp, megalopae, and green algae (26.30, 18.60 & 12.60% respectively) formed dominant food items of Abudefduf sexfasciatus. Fish larvae (8.70%), algal fragments (6.29%), medusae (4.13%), eggs (3.56%) and copepods (3.20%) were commonly recorded. Decapod larvae and bryozoans were occasionally recorded forming proportions of 1.70 and 1.22% respectively (Fig 44 A). Stomach contents of Amphiprion chrysogaster mainly contained fish larvae (28.90%) while other common food items were copepods (5.00%), molluscan larvae (3.00%) and shrimp (1.90%). Decapod larvae were rare (Fig 44 B). A. nigripes preferred fish larvae (43.00%). Decapod larvae and amphipods were commonly recorded with proportions of 7.50 and 4.60%. Eggs and copepods (1.22 and 1.20% respectively) were occasional food items. Algal fragments were rare (Fig 44 C).

Copepods constituted the major stomach contents of Chromis caerulea and C. dimidiata with proportions of 60.19 and 58.00% respectively. Common food items of C. caerulea were fish larvae (8.60%), eggs (7.50%) and shrimp (5.60%) while decapod larvae and algal fragments (3.28 and 1.60% respectively) formed occasional food items. Medusae were rare stomach contents (Fig 36 D). Fish larvae (15.70%) were common stomach contents of C. dimidiata. Decapod larvae, megalopae, shrimp and medusae were occasionally recorded (4.10, 3.60, 2.90 & 1.80% respectively). Cirripede larvae and eggs were rare (Fig 44 E).

Chrisiptera glauca preferred copepods (25.00%), green algae (15.50%) and algal fragments (12.60%) while fish larvae (5.50%) and amphipods (4.60%) formed common food items. Shrimp and eggs were occasionally recorded with proportions of 1.80 and 1.30% respectively (Fig 45 A). Green algae (27.90%) and shrimp (25.00%) were dominant food items of C. unimaculata. Fish larvae (10.00%), decapod larvae (8.60%) and eggs (8.30%) formed common stomach contents. Copepods, bryozoans and algal fragments were occasionally recorded forming proportions of 3.60, 2.00 and 1.60% respectively (Fig 45 B).

Dascyllus aruanus, D. reticulatus, and D. trimaculatus preferred copepods as food, where they accounted for 55.70, 30.16 and 30.00% of stomach contents respectively. In general, they exhibited a wider range of food preference than other pomacentrids. The common food items of D. aruanus were decapod larvae (13.00%), shrimp (10.00%) and fish larvae (5.00%). Ostracods, eggs, medusae and cirripede larvae were occasionally consumed forming proportions between 1.30 and 3.60%. Chaetognaths , megalopae, bryozoans, molluscan larvae, and green algae were rarely encountered (Fig 45 C). Common food items of D. reticulatus were fish larvae (10.80%), eggs (9.80%) decapod larvae (5.80%) and medusae (5.60%). Polychaetes, shrimp, ostracods, cirripede larvae, bryozoans and megalopae were occasional food items that formed proportions between 1.20 and 4.10%. Amphipods, chaetognaths and molluscan larvae were rare

(Fig 45 D). Apart from copepods, D. trimaculatus preferred fish larvae (23.00%) and eggs (11.70%). Ostracods (7.00%) were commonly recorded. Medusae, molluscan larvae, megalopae, shrimp, chaetognaths and amphipods were occassionally recorded with proportions between 1.30 and 4.70% (Fig 45 E).

Plectroglyphidodon phoenixensis mainly fed on green algae (42.10%), while algal fragments, eggs, and fish larvae (9.80, 9.00 & 8.30% respectively) were commonly recorded. Megalopae, bryozoans and shrimp were occasionally encountered forming proportions of 4.11, 3.60 and 2.00% respectively. Amphipods were rare (Fig 37 F). Green algae (43.80%) was the most dominant food item in Pomacentrus pavo. Amphipods (10.40%), algal fragments (8.40%) decapod larvae (6.00%) and copepods (5.00%) were common food items. Bryozoans and shrimp were occasionally consumed accounting for proportions of 2.60 and 1.08% respectively (Fig 45 G).

Stegastes lividus preferred green algae (35.90%) in its diets. Algal fronds (11.00%) and amphipods (5.00%) were commonly found. Shrimp, fish larvae, and copepods occasionally occurred in proportions of 3.40, 2.22 and 1.29% respectively (Fig 45 H). Amphipods (20.90%), green algae (19.40%), fish larvae (17.20%) and copepods (11.80%) dominated the stomach contents of S. nigricans. Decapod larvae, cirriped larvae, ostracods and medusae occurred occasionally forming proportions of 4.50, 3.20, 1.90 and 1.80% respectively (Fig 45 I). Semidigested contents in pomacentrids varied greatly between 3.00 and 61.00%.

Table 38. Percentage occurrence of food items in the guts of fourteen species of pomacentrids. (Number of fishes (N), size ranges in mm, feeding diversity- H').

SPECIES				FOOD ITEMS																
TABLE 38	POMACENTRIDAE	N	SIZE RANGE (mm)	COPEP	OSTRA	AMPHI	MOLU.L	CIRR.L	MEDU	FIS.L	EGGS	CHAETG	POLY.L	DECA.L	SRIMP	MEGLOP	G.ALGA	BRYO	ALGA.F	SDM	H'
1.	Abudefduf sexfasciatus	38	53 - 155	3.20	-	-	-	-	4.13	8.70	3.56	-	-	1.70	26.30	18.60	12.60	1.22	6.29	13.70	2.99
2.	Amphiprion chrysogaster	10	25 - 33	5.00	-	-	3.00	-	-	28.90	-	-	-	0.55	1.90	-	-	-	-	60.65	1.48
3.	A. nigripes	16	20 - 68	1.20	-	4.60	-	-	-	43.00	1.22	-	-	7.50	-	-	-	-	0.38	42.10	1.72
4.	Chromis caerulea	105	10 - 68	60.19	1.50	-	-	-	0.90	8.60	7.50	-	-	3.28	5.60	-	-	-	1.60	10.83	2.01
5.	C. dimidiatus	18	32 - 74	58.00	-	-	-	0.30	1.80	15.70	0.10	-	-	4.10	2.90	3.60	-	-	-	13.50	1.92
6.	Chrysiptera glauca	40	42 - 80	25.00	-	4.60	-	-	-	5.50	1.30	-	-	-	1.80	-	15.50	-	12.60	33.70	2.44
7.	C. unimaculata	121	40 - 75	3.60	-	-	-	-	-	10.00	8.30	-	-	8.60	25.00	-	27.90	2.00	1.60	13.00	2.70
8.	Dascyllus aruanus	175	10 - 66	55.70	3.60	-	0.30	1.30	2.70	5.00	2.80	0.60	-	13.00	10.00	0.41	0.22	0.40	-	3.97	2.26
9.	D. reticulatus	99	14 - 58	30.16	2.80	0.70	0.10	2.79	5.60	10.80	9.80	0.51	4.10	5.80	3.00	1.20	-	2.60	-	20.04	3.07
10.	D. trimaculatus	90	10 - 94	30.00	7.00	1.30	4.32	-	4.70	23.00	11.70	3.00	-	-	3.40	3.78	-	-	-	7.80	2.92
11.	Plectroglyphidodon phoenixensis	56	44 - 70		-	0.49	-	-	-	8.30	9.00	-	-	-	2.00	4.11	42.10	3.60	9.80	20.60	2.45
12.	Pomacentrus pavo	100	20 - 88	5.00	-	10.40	-	-	-	-	-	-	-	6.00	1.08	-	43.80	2.60	8.40	22.72	2.32
13.	Stegastes lividus	25	32 - 56	1.29	-	5.00	-	-	-	2.22	-	-	-	-	3.40	-	35.90	-	11.00	41.20	2.00
14.	S. nigricans	83	30 - 80	11.80	1.90	20.90	-	3.20	1.80	17.20	9.80	-	-	4 50	-	-	19.40	-	-	9.50	2.95

AMPHI - amphipods, ALGA.F - algal fragments, BRYO - bryozoans, CHAETG - chaetognaths, CIRR.L - cirripede larvae, COPEP - copepods, DECA.L - decapod larvae, EGGS - eggs, FIS.L - fish larvae, G.ALGA - green algae, MEGLOP - crab megalopae, MEDU - medusae, MOLU.L - molluscan larvae, OSTRA - ostracods, POLY.L - polychaete larvae, SRIMP - shrimp, SDM - semidigested matter.

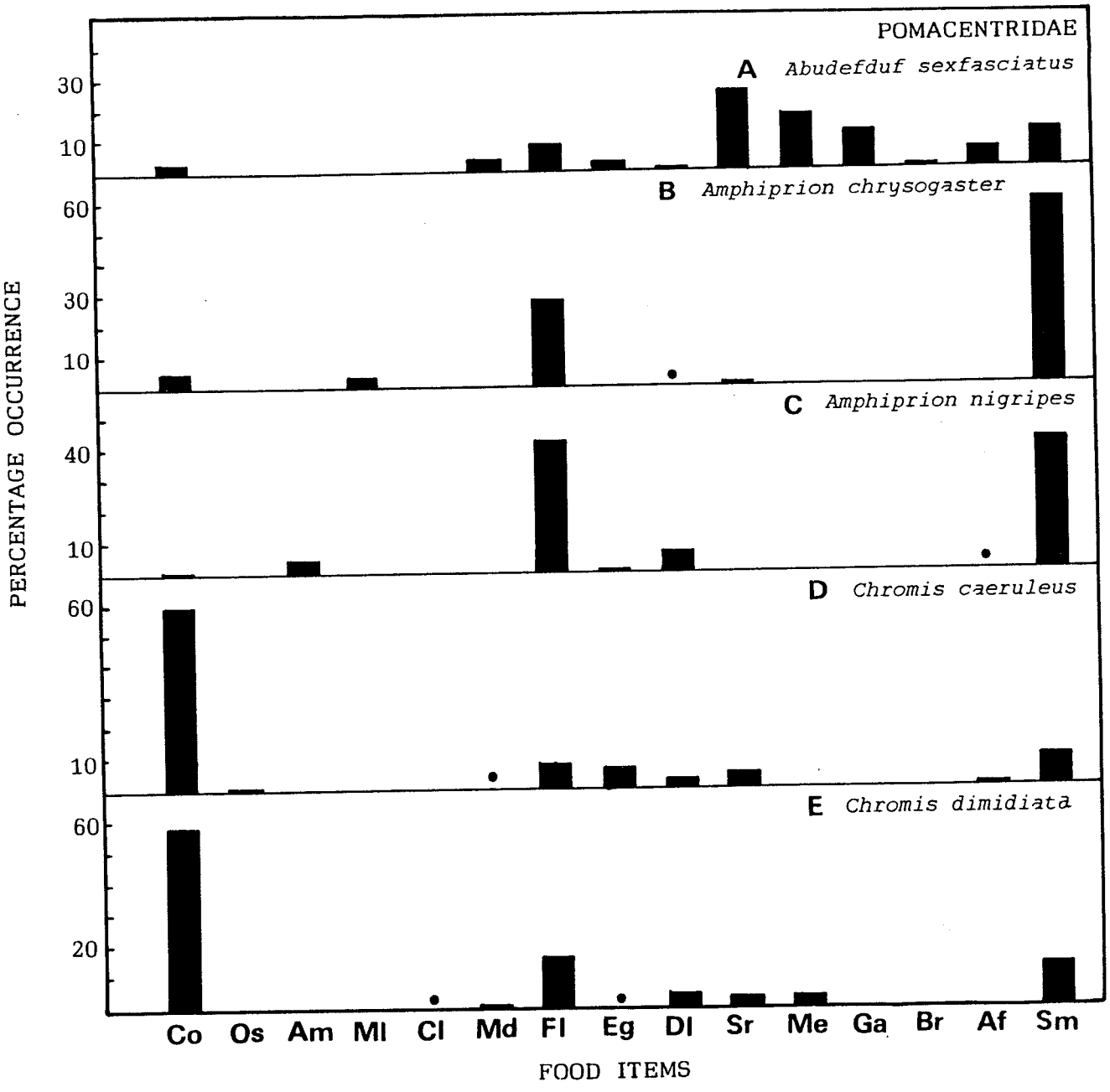

Figure 44. (A to E) Percentage occurrence of food items in the guts of five pomacentrids.

(Co - copepods, Os - ostracods, Am - amphipods, Ml - molluscan larvae, Cl - cirripede larvae, Md - medusae, Fl - fish larvae, Eg - eggs, Dl - decapod larvae, Sr - shrimp, Me - megalopae, Ga - green algae, Br - bryozoans, Af - algal fragments, Sm - semidigested matter) • less than 0.5%.

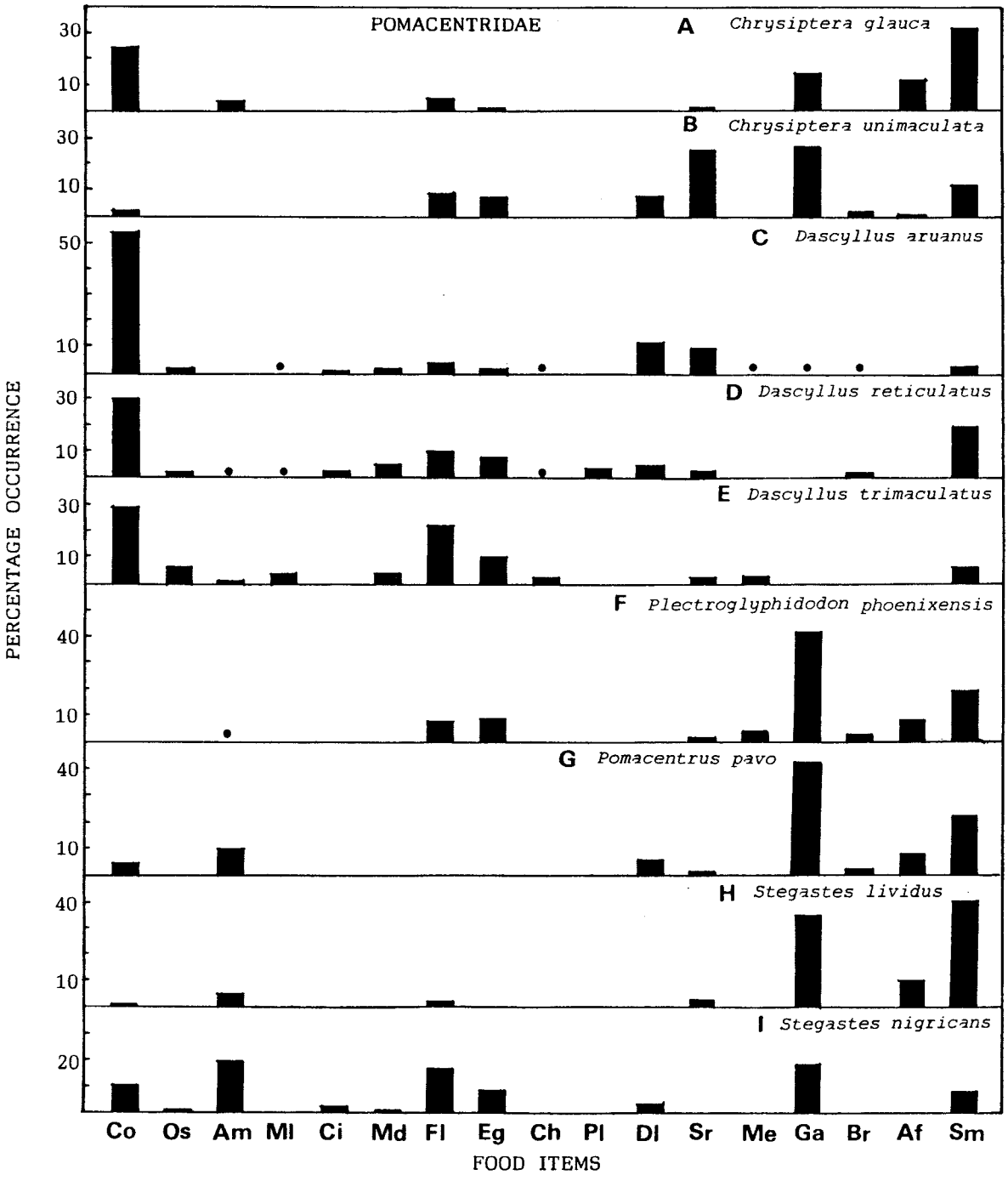

Figure 45. (A to I) Percentage occurrence of food items in the guts of nine pomacentrids.

(Co - copepods, Os - ostracods, Am - amphipods, Ml - molluscan larvae, Cl - cirripede larvae, Md - medusae, Fl - fish larvae, Eg - eggs, Ch - chaetognaths, Pl - polychaete larvae, Dl - decapod larvae, Sr - shrimp, Me - megalopae, Ga - green algae, Br - bryozoans, Af - algal fragments, Sm - semidigested matter) • less than 0.5%.

Feeding diversity of each pomacentrid is given in Fig 43 B. Highest feeding diversity was recorded by Dascyllus reticulatus (3.07) while relatively high H' values were recorded by Abudefduf sexfasciatus, Stegastes nigricans, and Dascyllus trimaculatus (2.99, 2.95 & 2.92 respectively). Other species recorded H' values above 2.00 except Chromis dimidiata and Amphiprion nigripes that showed H' values of 1.92 and 1.72% respectively. Least feeding diversity was recorded by A. chrysogaster (1.48).

24. Scaridae: Food preferences of five scarids and their feeding diversity (H') are given in Table 39. Three food items, namely green algae, algal fronds and crustacean remains were recorded from all species (Fig 42 C, D, E, F, G). Green algae was the dominant food item in all species studied with proportions generally ranging between 25.00 and 33.00% except in Scarus psittacus where it was 13.00%. Algal fronds formed significant stomach contents of S. sordidus, S. scaber and S. psittacus accounting for proportions of 19.88, 15.80 and 15.00% respectively. S. rubroviolaceus and S. viridifuscatus consumed relatively low quantities of algal fronds (9.80 and 7.80% respectively). Crustacean remains accounted for proportions between 0.50 and 1.20%. Stomachs contained large amounts of semidigested matter (48.90 to 71.50%) consisting of algal matter and sediment (coral origin).

H' values of scarids were generally low. S. scaber and S. sordidus recorded a feeding diversity of 1.53 each while the least was 1.18 in S. psittacus. S. viridifuscatus and S. rubroviolaceus showed H' values of 1.32 and 1.29 respectively.

25. Scorpaenidae: Food preferences of four species of scorpaenids and their feeding diversity (H') are given in Table 40. Food items encountered in the stomachs of Dendrochirus zebra indicated relatively low proportions ranging between 1.50 and 5.40. Fish (5.40%) and shrimp (4.60%) were common while amphipods and crabs accounted for 2.00 and 1.50% respectively (Fig 42 J). Pterois antennata predominantly fed on fish (48.89%) while crabs were commonly recorded, forming proportions of 5.43% (Fig 42 K) Fish, crabs and shrimp (23.86, 19.29 and 15.00% respectively) were preferred by P. miles while isopods (8.70%) and amphipods (6.32%) formed common food items (Fig 42 L). Fish (80.00%) formed the major stomach content in P. radiata while amphipods (6.00%) commonly occurred. Crabs (1.50%) were occasionally recorded (Fig 42 M). Semidigested matter in stomachs varied between 12.50 and 86.50%.

Feeding diversity of the four species was generally low except in P. miles where it was 2.43. P. antennata registered a H' value of 1.25. P. radiata and Dendrochirus zebra recorded low H' values (0.97 and 0.81 respectively).

26. Serranidae: 22 individuals of Cephalopholis argus in the size range of 140 to 300 mm were examined. They mainly fed on fish (53.02%). Cephalopods (12.45%), crab (9.90%) and stomatopods (5.90%) were commonly encountered. 2.73% of stomach contents was shrimp while 16.00% was semidigested matter (Fig 46 A). 80 individuals of Epinephelus hexagonatus in the size range of 43 to 240 mm were examined. Crabs (39.00%) were the most dominant food items while fish were commonly recorded (5.80%). Cephalopods and stomatopods occurred with proportions of 2.60 and 1.60% respectively. Semidigested matter formed 51.00% of the stomach contents (Fig 46 B). Nine individuals of E. tauvina in the size range of 94 to 166 mm were examined. Fish (40.30%) followed by crabs (11.29%) formed important food items while shrimp formed a proportion of 1.00%. Cephalopods were rare. Semidigested matter formed 46.70% of the stomach contents (Fig 46 C).

Cephalopholis argus recorded a feeding diversity of 1.99 while E. tauvina and E. hexagonatus showed H' values of 1.52 and 1.51 respectively.

27. Siganidae: 80 individuals of Siganus argenteus in the size range of 30 to 312 mm and 23 individuals of S. stellatus in the size range of 60 to 114 mm were examined. Seagrass formed the dominant food item in both species (45.00 & 58.90% respectively). S. argenteus preferred green algae (16.40%) and algal fronds (6.00%) with semidigested matter forming 32.60% of the stomach contents (Fig 46 D). S. stellatus preferred algal fronds (13.20%) and green

algae (7.50%) with semidigested matter forming 20.40% of the stomach content (Fig 46 E). S. argentus and S. stellatus recorded H' values of 1.72 and 1.59 respectively.

28. Tetraodontidae: Food preferences and feeding diversities of four species of tetradontids are given in Table 41. Canthigaster margaritata mainly fed on shrimp (40.11%). Gastropods, crabs and sponges were commonly consumed and accounted for proportions of 13.59, 12.30 and 8.00% respectively (Fig 46 F). C. valentini preferred shrimp (26.70%) and crab (16.00%). Sponges (3.00%) were recorded occasionally while gastropods were rare (Fig 46 G). Only gastropods (36.00%) were recorded from stomachs of Tetraodon nigropunctatus (Fig 46 H). Crabs and gastropods (15.50 & 12.00% respectively) formed the food items of T. hispidus (Fig 46 I). Semidigested matter formed 26.00 to 73.00% of the stomach contents in the four species.

Feeding diversity in Canthigaster margaritata was relatively high (2.09). C. valentini and Tetraodon hispidus registered H' values of 1.58 and 1.13 respectively. The least feeding diversity (0.94) was found in T. nigropunctatus.

29. Zanclidae: 24 individuals of Zanclus canescens in the size range of 63 to 124 mm were examined. Algal fronds (29.00%) dominated stomach contents. Significant quantity of green algae (16.60%), sponges (16.30%) and bryozoans (14.50%) were also recorded. Semidigested matter was 23.60% of stomach contents (Fig 46 J). Z. canescens registered a feeding diversity of 2.27.

Tables 39, 40 & 41. Percentage occurrence of food items in the guts of various species belonging to scaridae, Scorpaenidae and Tetradontidae, (Number of fishes (N), size ranges in mm, feeding diversity - H').

SPECIES				FOOD ITEMS				
TABLE 39	SCARIDAE	N	SIZE RANGE (mm)	G.ALGA	ALGA.F	CRUST.R	SDM	H'
1.	Scarus psittacus	43	73 - 200	13.00	15.00	0.50	71.50	1.18
2.	S. rubroviolaceus	30	230 - 346	25.70	9.80	0.70	63.80	1.29
3.	S. scaber	63	80 - 273	33.00	15.80	1.20	50.00	1.53
4.	S. sordidus	68	140 - 284	30.60	19.88	0.62	48.90	1.53
5.	S. viridifuscatus	91	156 - 312	30.80	7.80	1.00	60.40	1.32

TABLE 40	SCORPAENIDAE	N	SIZE RANGE (mm)	FISH	CRAB	ISOP	SRIMP	AMPHI	SDM	H'
1.	Dendrochirus zebra	10	125 - 180	5.40	1.50	-	4.60	2.00	86.50	0.81
2.	Pterois antennata	4	110 - 143	48.89	5.43	-	-	-	45.68	1.25
3.	P. miles	13	65 - 224	23.86	19.29	8.70	15.00	6.32	26.83	2.43
4.	P. radiata	7	100 - 174	80.00	1.50	-	-	6.00	12.50	0.97

TABLE 41	TETRAODONTIDAE	N	SIZE RANGE (mm)	GASTR	CRAB	SRIMP	SPONG	SDM	H'
1.	Canthigaster margaritata	33	35 - 75	13.59	12.30	40.11	8.00	26.00	2.09
2.	C. valentini	10	52 - 64	0.20	16.00	26.70	3.00	54.10	1.58
3.	Tetraodon nigropunctatus	8	260 - 334	36.00	-	-	-	64.00	0.94
4.	T. hispidus	6	170 - 309	12.00	15.50	-	-	72.50	1.13

ALGA.F - algal fragments, AMPHI - amphipods, CRAB - crabs, CRUST.R - crustacean remains, FISH - fish, G.ALGA - green algae, GASTR - gastropods, ISOP - isopods, SPONG - sponges, SRIMP - shrimp, SDM - semidigested matter.

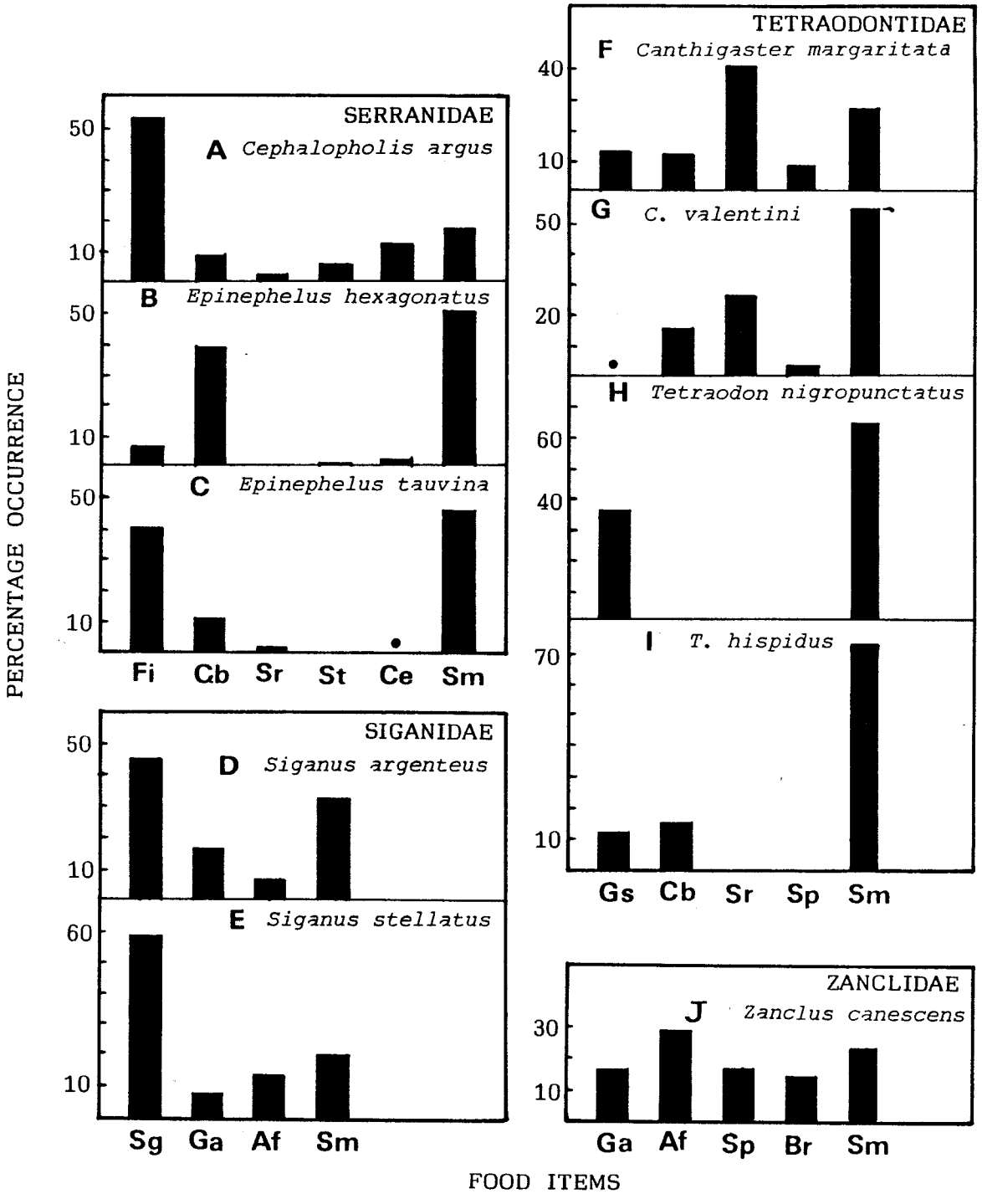

Figure 46. (A to J) Percentage occurrence of food items in the guts of various species of Serranidae, Siganidae, Tetraodontidae and Zanclidae.

(Af - algal fragments, Br - bryozoans, Cb - crabs, Ce - cephalopods, Fi - fish, Ga - green algae, Gs - gastropods, Sg - seagrass, Sp - sponges, Sr - shrimp, St - stomatopods, Sm - semidigested matter) • less than 0.5%.

B. FOOD AND FEEDING HABITS OF CORAL REEF FISHES OF THE GULF OF MANNAR REGION:

Information on prey preference and feeding diversity (H') of 26 commonly occurring species of coral reef fishes belonging to 7 families from the Gulf of Mannar region are given in this account.

1. Acanthuridae: A total of 63 individuals of Acanthurus dussumieri in the size range of 61 to 152 mm were studied. Filamentous algae (45.30%) dominated the gut contents, followed by brown algae (20.00%). Seagrass (8.60%) green algae (2.60%) and crustacean remains were found in low proportions. Semidigested matter accounted for 22.30%. The feeding diversity was 1.99.

2. Chaetodontidae: Filamentous algae and coral polyps (49.80 and 23.50%) formed significant prey items in Chaetodon auriga while sponges (5.80%), polychaete tentacles (5.60%) and algal fragments (1.20%) formed low proportions. The most dominant prey items in the guts of C. collare were filamentous algae (30.60) and polychaete tentacles (23.50%). Ascidians (10.70%) were commonly consumed while algal fragments, shrimp and amphipods appeared to be occasional food items (2.80, 2.30 and 1.60% respectively). C. decussatus preferred coral polyps, algal fragments and polychaete tentacles (30.00, 15.00 and 11.30% respectively). While sponges and anemones were commonly consumed (9.70 and 6.00% respectively). C. lunula preferred

amphipods (39.50%) and algal fragments (29.00%). Shrimp, ascidians, sponges and megalopae were observed in low proportions (5.40, 4.30, 3.60 and 3.50 respectively).

Chaetodon melannotus mainly fed on filamentous algae and polychaete tentacles (38.00 and 25.20% respectively). Coral polyps and sponges formed proportions of 15.60 and 5.40% respectively. Guts of C. octofasciatus contained more of algal fragments (36.50%) while polychaete tentacles (25.00%) and filamentous algae (23.00%) were consumed in almost equal quantities. Sponges (2.30%) were rare prey items. C. oxycephalus preyed upon sponges (33.40%) and anemones (31.50%) in nearly equal proportions while ascidians (19.00%) and algal fragments (14.00%) were common food items. C. plebeius had a narrow food range with only three prey items, namely, coral polyps (53.00%), filamentous algae (31.00%) and algal fragments (13.80%).

Chaetodon trifascialis mainly preyed upon coral polyps (35.20%) and polychaete tentacles (27.85) followed by sponges (10.30%) and filamentous algae (1.35%). C. trifasciatus preferred coral polyps (55.70%) while polychaete tentacles formed common food items (13.55%), sponges formed low proportions (2.60%). C. xanthocephalus fed mainly on polychaetes (48.63%) and algal fragments (25.30%). Other prey items were coral polyps (15.60%) and ascidians (3.60%). Semidigested matter in all chaetodontids accounted for proportions between 2.00 and 28.00%.

Feeding diversity (H') was the highest for Chaetodon decussatus (2.36) followed by C. collare and C. lunula (2.25 each). H' values above 2.00 were recorded by C. melannotus, C. octofasciatus and C. oxycephalus. Other species had H' values below 2.00 with the least in C. trifasciatus (1.53).

3. Holocentridae: 40 specimens of Sargocentron rubrum examined in the size range of 80 to 145 mm indicated that amphipods and copopeds formed major diets (30.80 and 16.30% respectively). Crabs (12.00%) fish (10.13%) and shrimp (8.33%) were commonly consumed. Semidigested matter accounted for 22.44%. This species recorded a H' of 2.06.

Twentyfive specimens of Myripristis murdjan were examined in the size range of 80 to 120 mm. Copepods (91.60%) and shrimp (23.95%) were dominant food, items. Fish (11.00%) and decapod larvae (8.46%) were common while molluscan larvae, ostracods and eggs were rare food items. Semidigested matter formed 6.43% of the gut contents, with a H' value of 2.31.

4. Labridae: Cheilinus undulatus mainly consumed stomatopods (33.20%) while gastropods (15.80%) and crabs (14.00%) were equally preferred. Crustacean remains (3.00) and fish (2.00) were rare prey items. Crabs and stomatopods (35.70 and 24.30% respectively) formed important gut contents of Halichoeres dussumieri while gastropods (12.00%) were commonly

consumed. Crustacean remains, sea urchins and shrimp formed proportions, of 3.00, 2.00 and 1.50% respectively. Hemigymnus melapterus restricted itself to stomatopods (43.50%) crabs (30.00%) and shrimp (16.00%). Thalassoma lunare consumed more of gastropods (36.23%) followed by shrimps (17.50%) and crabs (11.40%). Stomatopods (8.30%) starfish remains (8.20%) and fish (7.60%) were frequently preyed upon. Semidigested matter in the guts formed proportions between 1.81 and 2.55.

Thalassoma lunare recorded the highest H' value of 2.55 followed by 2.24 in Halichoeres dussumieri and 2.14 in Chelinus undulatus. The least H' of 1.81 was found in Hemigymnus melapterus.

5. Lutjanidae: 28 specimens of Lutjanus decussatus examined in the size range of 130 to 165 mm were found to feed on fish (72.70%) crab (14.50%) and sipunculids (3.00%). Semidigested matter accounted for 10.00% of the gut contents. H' recorded was 1.21.

Thirty specimens of L. fulviflammus examined in the size range of 75 to 160 mm fed on crabs (37.66%) amphipods (23.27%) and shrimp (10.00%). Semidigested matter formed 29.07% of the gut contents while H' recorded was 1.87.

Twentfive specimens of L. vittus examined in the size range of 100 to 160 mm preyed upon fish (26.50%), sipunculids (19.10%) and crabs (11.40%). Semidigested matter formed 43.00% of the gut contents while H' recorded was 1.84.

6. Pomacentridae: 43 specimens of Abudefduf sexfasciatus were examined in the size range of 60 to 110 mm. This species preyed on a wide variety of food items of which copepods (31.50%) and decapod larvae (24.70%) dominated. Except green algae (12.30%) which was present in significant quantity, rarely occurring items were shrimp (3.88%), eggs and molluscan larvae (2.10% each) and ostracods (1.00%). Semidigested matter accounted for 22.42% while the H' value was 2.75.

Thirtynine specimens of Chromis ternatensis were examined in the size range of 50 to 75 mm. Copepods and decapod larvae were the main food items (58.00 and 15.00% respectively). Other prey consumed were green algae (7.43%), molluscan larvae (3.2%) and ostracods (1.10%). Semidigested matter consisted of 15.27% of the gut contents while H' recorded was 1.77.

7. Haemulidae: 20 specimens of Diagramma pictum in the size range of 85 to 210 mm were examined. Fish was the dominant food item (23.10%) followed by crabs (14.70%), shrimp (12.00%) stomatopods (12.00%), amphipods (2.30%) and gastropods (3.00%). Semidigested matter constituted of 26.40% while H' recorded was 2.60.

Thirtysix specimens of Plectorhinchus gaterinus examined in the size range of 100 to 210 mm were found to consume mainly crabs (31.50%) and fish (23.00%). Amphipods, starfish remains and sipunculids formed low proportions (9.60, 3.90 and 2.00% respectively). Semidigested matter accounted for 30.00% of the gut contents. H' recorded was 2.17.

Fortythree specimens of P. schotaf examined in the size range of 80 to 180 mm were found to feed on crabs (20.77%), starfish remains (17.60%) and fish (15.10%); other items found in low proportions were stomatopods (7.30%), shrimps (5.80%) and sipunclids (1.00%). Semidigested matter accounted for 25.95% of the gut contents. H' recorded was 2.81.

DISCUSSION

Coexistence in a highly species rich environment demands resource sharing among coral reef fishes. The important resources are food and shelter for which competition is intense. Therefore, fishes have developed specializations in their modes of life to coexist. One such specialization is the diversity of feeding habits existing in these fishes. Food preferences vary between families and between species in each family. In certain cases where food preferences are same, resource sharing takes place through differences in morphology of mouth parts, habitat preferences or diurnal/nocturnal activity. The following section elucidates various aspects of the feeding biology in commonly occurring species of coral reef fishes from Lakshadweep and Gulf of Mannar region.

Food and feeding habits of coral reef fishes of Lakshadweep.

Acanthuridae: Most of the acanthurids ate green filamentous and brown algae resulting in lower feeding diversities but those species that fed on more prey items in addition to algal components, indicated a higher feeding

diversity. Robertson et al. (1979) observed a greater feeding flexibility in A. leucosternon and therefore could feed on smaller, more sparsely distributed algae in crevices. According to them, A. leucosternon should have had a greater feeding diversity owing to a variety of prey groups but in the present investigation, it indicated the least H' value (0.53) perhaps due to consumption of the abundant and easily available green algae. A. mata was reported to be a grazer and fed on filamentous algae on Marshall Islands (Hiatt and Strasburg, 1960) while in Hawaii it fed on diatoms and detritus (Jones, 1968). In the present study, only green algae and the semi-digested matter containing sand as a component were found. The category green algae here is assigned to unidentifiable green matter but it could possibly be filamentous algae in a digested form. A. triostegus fed on filamentous algae (Hiatt and Strasburg, 1960; Jones 1968) while green algae predominated gut contents in the present study. The reasoning given for A. mata perhaps holds good for this species. A. xanthopterus fed on filamentous algae in Marshall Islands (Hiatt and Strasburg, 1960) while in Hawaii they fed on diatoms and detritus (Jones, 1968). In the present study, it contained a small proportion of crustaceans and polychaetes in addition to algae suggesting that the species could not only graze on algae but makes use of small invertebrates associated with algae.

A. dussumieri not only consumed filamentous algae but also seagrass in low proportions. In other respects, it was in accordance with observations of Jones (1968). A. lineatus browsed on filamentous algae (Hiatt and Strasburg, 1960) and algal turfs (Robertson and Gaines, 1986).

This species was found to form large colonies where they defended territories containing thick algal mats (Robertson et al., 1979). In the present study, the feeding habits of A. lineatus were in aggrement with previous reports. A relatively higher H' could be due to inclusion of various types of algae while feeding on turf. A. nigricauda had feeding behaviours similar to A. lineatus but did not contain filamentous algae. This is perhaps due to the depth preference of this species where filamentous algae do not flourish. Most of the gut contents in Ctenochaetus strigosus were in a digested form but the occurrence of significant quantities of small crustaceans, shrimp and polychaetes indicated the consumption of detritus. Similar observations were made by Robertson and Gaines (1986). Major food items in Acanthurus leucosternon, A. lineatus, A. triostegus and Ctenochaetus strigosus from Minicoy atoll, Lakshadweep were filamentous and coralline algae (Pillai et al., 1992).

The observations on Naso lituratus in the present study were similar to those of Hiatt and Strasburg (1960) and Jones (1968) who found foliose and filamentous brown algae. Choat (1991) found this species to feed on macroscopic algae. Food preferences of N. unicornis tallied with the observations of Hiatt and Strasburg (1960) and Jones (1968) and Choat (1991) who stated that it feeds on larger algal species. But the occurrence of small invertebrates is perhaps accidental and were responsible in raising the H' value (1.84). The preference of filamentous algae and green algae in Zebrasoma veliferum confirms observations by previous workers (Hiatt and Strasburg 1960; Jones, 1968). Thus, it is evident from overall low H' values, that acanthurids depend on a narrow

range of algal species while low proportions of small invertebrates are ingested along with algal food.

Apogonidae: Apogonids were observed to be planktivorous. A wide range of prey items kept H' values high (above 2.00) in all species, crustaceans dominating the prey. The major prey of most nocturnal reef planktivores are among the large semipelagic residents of the local habitat that rise into the water column at night (Hobson, 1974; Hobson and Chess, 1978), and such invertebrate fauna is abundant on seagrass beds (Weinstein and Heck, 1979; Bell and Pollard, 1989). Apogonids were mainly collected with seine nets on seagrass beds at night and therefore, they seem to have consumed the diverse prey groups. In the present study, it was observed that the 6 apogonid species almost had similar prey preferences. Among these, Apogon kallopterus showed the highest feeding diversity with 7 to 8 prey categories represented equally. A similar pattern was evident in A. fraenauts. The other species indicated preference towards particular groups (A. leptacanthus preferred amphipods while A. quadrifasciatus preferred small crabs). Dominance of copepods in A. taeniophorus and Apoginichthys ocellatus indicates that they consumed plankton diurnally as copepods were generally not dominant at night. Hiatt and Strasburg (1960) found that most cardinal fishes (apogonids) had similar food habits. Among the six tuna bait fishes studied in the Solomon Islands, a single apogonid, Archamia zosterophora ate nectonic zooplankton where copepods (28.04%), caridian shrimp (10.05%) and brachyuran larvae (14.02%) dominated the food items (Milton et al., 1990). Analyses of the food

habits of these fishes indicates that among nocturnal apogonids, 'specialist' or 'generalist' categories cannot be recognised.

Balistidae: Predominance of crabs, alpheid shrimp, stomatopods and sea urchin remains suggest that most of the balistids were benthic carnivores while some were omnivores. Goldman and Talbot (1976) termed balistids as omnivores. Odonus niger consumed the greatest variety of prey (H' = 2.83) indicating slight tendency towards zooplanktivory. Apart from diet data, their occurrence in deeper waters near the reef slope or reef edge support the fact. Melichthys indicus exhibited an omnivorous feeding habit as it consumed significant amounts of algae along with other invertebrates. A single specimen of M. vidua examined at Marshall Islands contained bitten and scraped algal fronds, xanthid crab fragments, copepods, pelecypods and gastropods (Hiatt and Strasburg, 1960) while M. niger was termed as an omnivore that feeds mostly on drifting algal fragments, zooplankton and benthic vegetation (Hobson, 1974). In addition to algae and invertebrates, Randall (1967) reported seagrasses as a diet component. A higher proportion of small fish consumed by Balistapus undulatus is possibly because of its preference to deeper water (reef slope). Hiatt and Strasburg (1960) observed tips of coral, fish, crustaceans, gastropods and algae in equal proportions in its diet and was termed as an omnivore. In the present study, it was found to feed only on fish and crustaceans. Balistoides viridiscens consumed living tips of Pocillopora damicornis but ate sea urchins and starfishes (Hiatt and Strasburg, 1960). In the present study, remains of corals were not observed but crabs predominated the diet. Canthidermis maculatus was an

oceanic species and these were collected around floatsams during tuna fishing trips. A pelagic habitat, high incidence of copedods and small fish as diet suggest a zooplanktivorous habitat. Pseudobalistes flavimarginatus consumed crustaceans, gastropods, foraminiferans and tunicates (Hiatt and Strasburg, 1960). In the present study, crabs formed the bulk of the diets while algae also formed significant quantities. Rhinecanthus aculeatus, R. rectangulus and Sufflamen bursa showed similar preference with crustaceans and sea urchins dominating the food items. Hiatt and Strasburg (1960) found R. aculeatus to be a heterogenous feeder that takes anything organic (soft or hard-bodied) while R. rectangulus foraged primarily on algae and crustaceans. Hobson (1974) observed R. rectangulus as a diurnal omnivore feeding mostly gammaridean amphipods and other small organisms, while stomachs of S. bursa had echinoids and amphipods as major prey items apart from 18 other categories. Between S. chrysopterus and S. fraenatus, the former indicated a narrow feeding niche. In general, species of the genus Rhinecanthus and Sufflamen shared similar diets with crustaceans and sea urchins.

Caesionidae: Food habits of Caesio caerulaures from Lakshadweep were in accordance with observations made by Kuile (1989) from Flores Sea who observed copepods and chaetognaths to be dominant prey, excepting that chaetognaths were replaced by small fish (perhaps in their planktonic phase).

Chaetodontidae: Fluctuation in H' values (0.48 to 2.51) indicated that chaetodontid species have a wide range of feeding habits. Apart from

coral polyps that dominated diets of Chaetodon auriga, the presence of other food items (filamentous algae, polychaete tentacles, other small invertebrates) confirm the observations of Burgess (1978) who categorised it as a general omnivore; Harmelin-Vivien and Bouchon Navaro (1983) observed the dominance of coral polyps (60.91%) and sedentary polychaetes (13.03%); Harmelin-Vivien (1989) found a greater proportion of polychaetes (57.80%) and H' value of 1.73; Sano (1989) categorised it as a facultative coral feeder with a H' value of 1.60; Vijay Anand (1990 a) found that stomach contents were dominated by green algae and polychaetes. Pillai et al. (1992) recorded filamentous algae, copepods, sea anemones and sand particles in the guts of C. auriga. High H' values of C. auriga in the present study were due to a variety of prey items consumed. Further, its occurrence on all sub-habitats (Chapter III) reflects its generalised feeding behaviour. In the present study, C. cirtrinellus was found to have consumed more of filamentous algae also recorded by Harmelin-Vivien and Bouchon-Navaro (1983). These species were termed as non-coral feeders (Galzin, 1987 b) and also as facultative coral feeders/omnivores with H' values of 1.87 by Sano (1989). As C. collare shared similar food preferences with C. aurga and C. citrinellus, it could be termed as a general omnivore. Though coral polyps were consumed by C. falcula, the dominance of polychaete tentacles changed its feeding habits at Lakshadweep when compared to the observations of Talbot (1965) who stated this species to be a coral feeder.

A high H' value (2.51) indicated the diversity of prey consumed by C. kleinii. The occurrence of small planktonic prey and benthic

filamentous algae is suggestive of an omnivorous/zooplamktivorous feeding habit. Zooplanktivory in C. kleinii was observed by Burgess (1978) but the species can substitute its diets with benthic organisms. Anderson et al. (1981) found it to feed on soft corals but at times shifts to planktivory. It also consumed corals (70.00%) (Harmelin-Vivien, 1989) while it was classified as a facultative coral feeder/omnivore with a H' of 1.60 (Sano, 1989). The observations on these species indicate highly flexible feeding habits. C. lunula preyed upon a wide range of food items but predominance of polychaetes (54.00%) did not account for a high H' (2.13). Hiatt and Strasburg (1960) examined only one specimen which contained coral polyps while Hobson (1974) found benthic invertebrates preyed upon at night. Nocturnal behaviour was also reported by Findely and Findley (1989). Harmelin-Vivien (1989) observed dominance of coral polyps with H' of 0.62 while Sano (1989) termed this species as a non-coralline invertebrate feeder with a H' value of 0.65. Observations of Pillai et al. (1992) differed from previous observations in the sense that C. lunula fed on filamentous algae, anthozoans, polychaetes and sponges. The difference in H' values between previous reports and the present study could be due to differential preferences on invertebrate groups involved in the diets or variation in calculation procedure.

C. melannotus indicated a narrow feeding niche with three prey items of which polychaetes dominated. Observations in the present study differed from other reports which indicated C. melannotus to be coral feeders (Talbot, 1965), soft coral feeders (Anderson et al., 1981) their association with live coral cover (Adrim and Hutomo, 1989).

Among the two obligate coral feeders, C. trifascialis and C. trifasciatus (Hiatt and Strasburg, 1960; Anderson et al., 1981; Reese, 1981; Harmelin-Vivien and Bouchon-Navaro, 1983; Harmelin-Vivien, 1989; Irons, 1989; Sano 1989) the former appeared to be a specific coral feeder while the latter could also feed on polychaete tentacles. Counts of corallivores, as Reese (1981) and Hourigan (1989) proposed could indicate the health of the environment as they depend on corals for food. However, conclusions cannot be drawn due to lack of previous information on these species. Food habits of C. vagabundus in the present study indicate specific coral feeding with rather low H' value of 1.19, while in other observations they mainly consumed filamentous algae (22.5%), polychaetes (21.2%) and molluscan eggs (19.9) with a H' value of 2.56 (Harmelin-Vivien, 1989). Sano (1989) classified C. vagabundus as a facultative coral feeder/omnivore. C. xanthocephalus was found to be a coral feeder (Talbot, 1965) while ascidians and polychaetes constituted 80.00% .of the diet with a H' of 1.58 (Harmelin-Vivien, 1989). In the present study, it consumed more of filamentous algae. Low proportions of coral polyps and the presence of other food items possibly make this species an omnivore.

Forcipiger flavissimus and F. longirostris recorded the least H' values (0.89 and 0.48) as they consumed a narrow range of food items perhaps due to limitations posed by morphology of their snouts. The variation of length of snouts and the functional morphology possibly avoids competition between the two which share similar food habits (Chapter II, Figs. 9, 10). Hobson (1974) observed diets of F. flavissimus to contain torn pieces of larger benthic animals while F. longirostris fed mostly on

shrimp . These observations are in agreement with the present study. Burgess (1978) found that F. flavissimus could tear its prey with a forceps-like snout while the latter took in prey as a whole owing to its tube-like mouth. Harmelin-Vivien and Bouchon-Navaro (1983) made similar observations, but recorded a greater range of food items in F. flavissimus and a low H' value (0.41) for the same species was given by Sano (1989).

Heniochus acuminatus and H. monoceros shared similar food habits but H' in the latter was higher (2.13) as prey categories were preferred in equal proportions while H. acuminatus showed dominance of filamentous algae and amphipods. Sano (1989) grouped H. monoceros as a non-coralline inverterbrate feeder with no feeding diversity.

In general, the chaetodontids of Lakshadweep did not record low H' values (0.00) as in the case of similar species studied by Harmelin-Vivien in Moorea and Tulear (1989) and Sano in Japan (1989). This is possibly due to a non-specialized feeding behaviour, and a certain degree of adaptability that could occur with change in environmental conditions.

Cirrhitidae: Cirrhites pinnulatus and Paracirrhites forsteri shared similar feeding habits excepting that the latter species did not consume crabs. The difference is perhaps due to their behavioural patterns. C. pinnulatus was reported to remain under partial cover during day and is a noturnal predator on xanthid crabs (Hobson, 1974). This is in accordance with observations in the present study where 74.10% of the gut contents were crabs. It is also possible that the nocturnal habit of C. pinnulatus suits

the nocturnal occurrence of a majority of decapod crustaceans. Many polychaetes, molluscs and crustaceans hide during the day but are active at night and these are important foods for most nocturnal benthic feeders (Goldman and Talbot, 1976). P. forsteri preferred small fishes as their diet in Marshall Islands and Hawaii (Hiatt and Strasburg, 1960; Hobson, 1974) and was the same in Lakshadweep.

Diodontidae: Food of Diodon histrix from Lakshadweep differred from specimens examined by Hiatt and Strasburg (1960) who found only gastropods, crustaceans and foraminiferans; and Hobson (1974) stated that it is a nocturnal predator feeding mainly on echinoids. Though crustaceans were consumed by D. histrix, diets were dominated by coral fragments. Randall (1974) reported coral fragments in diodontids.

Fistulariidae: Observations on food preferences of Fistularia petimba from Lakshadweep are in accordance with reports of Hiatt and Strasburg (1960) and Hobson (1974) in the sense that they are exclusive piscivores. However, an insignificant proportion constituted by shrimp (3.00%) was perhaps accidental ingestion.

Grammistidae: Grammistes sexlineatus was rare in Lakshadweep and showed feeding behaviours similar to Paracirrhites forsteri in selectively consuming small fish and shrimp.

Haemulidae: The difference in food habits of Plectorhinchus gibbosus and P. orientalis possibly arise from their habitat preferences. The former inhabits deeper waters while P. orientalis was observed to migrate on to

shallow habitats for food. The dominant prey constituted of fish, crabs and gastropods. Schools of haemulid fishes feed among seagrass beds at night and rest over coral heads by day (Meyer et al., 1983). Sessile invertebrates other than corals are especially abundant on the hard substrates of reef and are also well represented in shallow surrounding habitats (Parrish and Zimmerman, 1977; Vacelet and Vasseur, 1977). It is possible that these reef dwelling species obtained a wide range of prey from such shallow habitats.

Holocentridae: All holocentrids were found to be nocturnal in behaviour. All species of the genus Neoniphon and Sargocentron characteristically fed on fish, crabs, and shrimp that were associated with benthic habitats while Myripristis adustus and M. murdjan were nocturnal water - column feeders. A variety of prey items in the latter resulted in relatively high H' values (2.17 to 2.46). Neoniphon sammara on seagrass beds could have gained more access in obtaining stomatopods which were represented in significantly higher proportions, and this was supported by a higher H' value (2.25). Among the benthic prey consumed, crabs which are most active at night clearly dominated gut contents. Holocentrids in the two groups, namely, bottom feeders and water-column feeders were described by Hiatt and Strasburg (1960) and Hobson (1974). Myripristis adustus and M. murdjan shared a similar diet with the dominance of decapod larvae and copepods. The dominant diets reported for M. murdjan were shrimp fragments (Hiatt and Strasburg, 1960) crab megalopae (Hobson, 1974), megalopae, decapods and stomatopods (Kuile, 1989).

Dominant prey in Neoniphon sammara were crab fragments (Hiatt and Strasburg, 1960), xanthid crabs and caridean shrimp (Hobson, 1974). In the present study, apart from crabs and shrimp, fish and stomatopods also formed significant proportions. Vivien and Peyrot - Calusade (1974) reported N. sammara to be a seagrass-dweller where polychaetes as prey items were less significant. N. opercularis, in contrast seemed to prefer larger prey and therefore consumed only crabs and fish (H' of 1.08 was the lowest in the group). This species was reported to be the largest holocentrid (Smith and Heemstra, 1986). Sargocentron diadema consumed gastropods, polychaetes, xanthid crabs, isopods, pelecypods (Hiatt and Strasburg, 1960); xanthid crabs, ophiuroids, crab megalopae, caridean shrimp, prosobranch gastropods (Hobson, 1974). Vivion and Peyrot - Clausade (1974) found polychaetes to be important prey. Apart from items already reported, S. diadema also consumed small fish. Food habits of S. spiniferum from Lakshadweep were similar to observations made by Hiatt and Strasburg (1960) and Hobson (1974) in the sense that they mainly fed on crabs and shrimp. A small proportion of juvenile fishes were also ingested. Diet of S. caudimaculatum was similar to that of S. spiniferum while the diet of S. violaceum was similar to that of S. diadema, except for inclusion of sipunculids in S. caudimaculatum and S. violaceum. To avoid competition owing to similar diet preferences, these species perhaps vary in their habitat preferences; the data on which is lacking. Difference in habitat preferences between Neoniphon opercularis and N. sammara was evident from collection areas. The former being a larger species, inhabited the massive coral region while the latter could be easily obtained from shallow seagrass beds.

Kuhlidae: Based on the prey items, H' of 2.03 schooling nature and water-column dwelling, Kuhlia mugil could be termed as a zooplanktivore. Feed constituted mainly of copepods and fish larvae. Hobson (1974) stated K. sandvicensis as a nocturnal predator feeding on free swimming crustaceans.

Kyphosidae: With only two prey items of plant origin (Gracilaria sp. and filamentous algae), Kyphosus cinerascens could be termed as a herbivore, other observations state that guts of this species contained fronds and filaments of red and brown algae (Hiatt and Strasburg, 1960) and a wide variety of benthic algae (Hobson, 1974). Further, Hobson observed this species in groups of 10 or more with an uncertain nocturnal habit. Observations in the present study suggest that this species is active during day and night but seems to feed at night. In one instance, a large group of about 50 individuals were observed feeding on seagrass beds and nocturnal gill net operations on the reef flat captured 40 to 60 individuals.

Labridae: Of the 28 species of wrasses (Labridae) only 20 species had relatively low H' values while others showed higher values (2.02 to 2.88) due to a wide range of food items consumed. The semidigested matter that accounted for significant proportions mainly consisted of hard parts of the prey. All the prey categories are mainly grouped under molluscs, crustaceans, echinoderms, fish and small soft bodied invertebrates. Most wrasses are reported to feed on bottom dwelling invertebrates, especially hard-shelled forms, though some pick small free-swimming animals from the water column. A few others feed exclusively on ectoparasites (Fischer and Bianchi, 1984).

Anampses caeruleopunctatus predominantly fed on crabs, alpheid shrimp and gastropods. Hobson (1974) described the feeding habits of A. cuvier which fed on amphipods. Bodianus axillaris mainly fed on small fish perhaps due to its semi-pelagic nature. B. bilunulatus examined by Hobson (1974) fed on molluscs. Strand (1988) reported that B. diplotaenia was found to feed on small invertebrates and fish. Most of the species belonging to the genus Bodianus were stated to be deep water dwellers (Fischer and Bianchi, 1984) and their intermittent association with reef substratum possibly brings in diet variations. The four species of the genus Cheilinus fed predominantly on crabs and gastropods.

Cheilinus chlorurus was reported to feed on crabs and gastropods (Hiatt and Strasburg, 1960) while C. trilobatus mainly consumed fish, crabs, shrimps and gastropods (Hobson, 1974). In the present study, fish formed an insignificant portion of the diet of C. trilobatus but echinoderms formed sizeable proportions. Fischer and Bianchi (1984) mentioned that the diets of C. digrammus and C. undulatus mainly consisted of molluscs, crustaceans and seaurchins. Food preferences of these species from Lakshadweep were similar to previous reports with respect to major prey items but certain differences occurred with insignificant food categories.

Cheilio inermis fed mainly on crustaceans (Fischer and Bianchi, 1984) and a similar diet was observed in specimens examined at Lakshadweep. Coris formosa and C. gaimard had similar diets but the latter had a higher H' value (2.88) because of its preference for other prey items constituting lobster remains, fish and some unidentifiable crustacean remains. Hiatt and Strasburg (1960) found only gastropods,

pelecypods and shrimp , while Hobson (1974) recorded molluscs, echinoids and crabs. Observations in the present study were similar to earlier reports.

Gomphosus varius had a lower feeding diversity (H' = 1.66) as if specifically seemed to feed on shrimp and stomatopods. In contrast G. coeruleus had a higher feeding diversity (H' = 2.53) owing to a greater variety of prey with shrimp and echinoids as dominant prey items. This difference is perhaps due to varying habitat preferences and morphological abilities in prey procurement with their elongated snouts. Hobson (1974) observed G. varius to consume larger crustaceans from reef crevices while Hiatt and Strasburg (1960) found alpheid shrimps and xanthid crabs frequently. Observations on gut contents of G. varius differed from previous reports in the sense that gastropods and crabs were not consumed and proportion of alpheid shrimps was negligible.

Gastropods and crabs clearly dominated the prey items in all species of the genus Halichoeres from Lakshadweep. Pelecypods and alpheid shrimps formed an insignificant proportion. Diets of Halichoeres centiquadrus and H. marginatus were similar to those found by Hiatt and Strasburg (1960) except that in the former polychaetes formed low proportions. A H' value of 1.62 as compared to 2.13, 2.22 and 2.77 in other species indicates that H. centiquadrus requires a specialized diet. Vijay Anand (1990a) reported that this species fed mainly on gastropods, crabs, polychaetes and shrimp . Diet of H. marginatus differed from previous observations in not representing polychaetes. H. nebulosus and H.

scapularis shared similar diets but the latter had a relatively higher H' value of 2.71 indicating a greater feeding diversity. Aronson and Sanderson (1987) found H. garnoti to be attracted to foraging goatfish which provided access to an otherwise unavailable food resource from sand.

Among the two species of the genus Hemigymnus, H. melapterus had a higher H' (2.64) though prey preferences were similar to that of H. fasciatus. This resulted due to consumption of higher quantities of prey in equal proportions. Hiatt and Strasburg (1960) found gastropods as dominant prey items in H. melapterus while crustaceans, formainiferans and algae were consumed in lesser quantities. In the present study, they contained less of gastropods but more of crabs, sea urchins and stomatopods. Hologymnosus doliatus had similar food preferences with Bodianus axillaris in the sense that both species predominantly fed on fishes. In comparison, the former showed a greater feeding diversity (H' = 1.42) because of its association with shallower habitats (rubble and seagrass) where it perhaps fed on benthic invertebrates.

A greater proportion of crustacean remains in the guts of Labroides bicolor and L. dimidiatus could have resulted from cleaning host fishes of crustacean ecto-parasites. A greater H' value (1.62) in L. bicolor is due to a relatively free-swimming nature (Smith and Heemstra, 1986) which perhaps provided access to other prey items. Hourigan (1989) stated that a generalised diet in chaetodontids will increase the apparent evenness of resource distribution and in contrast, a specialized feeder is likely to encounter a patchy distribution. With some modifications in point of view

of behaviour or habitat preference, the same statement could be put as "a generalized habitat preference (in L. bicolor) could increase the feeding diversity while a territorial behaviour (in L. dimidiatus) could result in specialized feeding." However, as these are 'cleaner species' their diets could be determined by the types of ecto-parasites that host fishes carry.

In a single specimen of Novaculichthys taeniourus, Hiatt and Strasburg (1960) observed one alpheid shrimp. In Lakshadweep, this species occurred commonly, and 25 specimens examined revealed the dominance of crabs, alpheid shrimps, a variety of other crustaceans and echinoids. Among the three species of the genus Stethojulis, S. albovittata indicated a lower H' of 1.90 due to specific preference to gastropods. In general, the prey in all three species was similar with preference for gastropods, shrimp and crabs. S. axillaris (Hiatt and Strasburg, 1960) consumed more of polychaetes while an unidentified species, Stethojulis sp. consumed more of crustaceans and gastropods. These species appear to have small body sizes and were mainly collected from seagrass beds from where they probably obtained epiphytic gastropods and crustaceans.

Among the four species of the genus, Thalassoma, T. purpureum had a higher feeding diversity (H' = 2.45) which is due to consumption of a wide variety of prey. Hiatt and Strasburg (1960) found T. hardwicki to have fed on crabs, their zoea and megalopa stages and shrimp larvae. In the present study, crabs followed by gastropods were most dominant while other crustaceans formed low proportions. The lowest feeding diversity (H' = 2.07) among the four species was found in T. herbraicum due to

specific preference for gastropods. T. lunare differed from all the rest in consuming eggs, polychaetes and fish. A variety of feeding preferences noticed in this genus is perhaps to avoid competition. The ten species of labrids studied by Pillai et al. (1992) were found to consume mainly crabs, alpheids and fishes, while preference towards gastropods was not indicated.

Most labrids have been classified as carnivores on benthic fauna (Hiatt and Strasburg, 1960) and some of them are highly specialized predators (in parasite picking) (Goldman and Talbot, 1976). Large wrasses fed mainly on larger bivalves, gastropods and hermit crabs (Thompson and Jones, 1983; Jones, 1984) while they were observed to avoid areas of increased algal cover and fed on benthic invertebrates, crabs and gastropods (Choat and Ayling, 1987). To suit these feeding habits in most wrasses, intestinal folds compensate for the absence of a true stomach. (Verigina and Kobegenova, 1987; Vijay Anand, 1990a).

Lethrinidae: The prey of Gnathodentex aureolineatus constituted mainly of xanthid crabs, gastropods, polychaetes and fish (Hiatt and Strasburg, 1960). Apart from insignificant quantities of crustaceans consumed, this species mainly preyed upon polychaetes in Lakshadweep. Fischer and Bianchi (1984) reported its diet to be bottom-living invertebrates and in the case of Lethrinus ornatus diets constituted of crustaceans, molluscs, echinoderms and small fishes. Observations on the diet of L. ornatus examined in Lakshadweep were similar excepting that echinoderms and molluscs were not consumed. Food preference of L. xanthochilus was mentioned as crustaceans and small fishes (Fishcer and Bianchi, 1984); the

former group also recorded in the present study but fishes were replaced by polychaetes. H' was low due to a narrow food niche. Hobson (1974) found that crabs formed low proportions in the food of Monotaxis grandoculis from Hawaii, while gastropods, ophiuroids and echinoids were dominant. In the present study, crabs dominated as prey items with other groups remaining in low proportions. Goldman and Talbot (1976) stated that carnivorous fishes in general take the commonest foods available to them, i.e., available within size and catching limitations in their habitat and this could possibly explain the differences observed in lethrinid diets from Lakshadweep.

Lutjanidae: The lowest H' value (0.95) in Aprion virescens resulted due to a single prey item (fish) which it procures from the water column. Lutjanus bohar and L. gibbus shared similar food preferences. A greater proportion of fish consumed by L. bohar is suggestive of feeding from the water column while dominance of crabs indicates a benthic carnivore tendency in L. gibbus. Hiatt and Strasburg (1960) also reported similar food habits for the two species from Marshall Islands. Diet of L. gibbus from Society Islands considered of fish and crustaceans (xanthid crabs and stomatopods) Randall and Brock, 1960. Fishes, crustaceans, molluscs and algae in the stomach contents of L. bohar from Papua New Guinea were reported by Wright et al. (1986). Diets of L. kasmira from Lakshadweep differed slightly from those found by Rangarajan (1970) in the sense that crabs, shrimp and fish dominated in specimens from Lakshadweep while in the latter, fish, juvenile crabs, megalopae and young prawns were chief items. Further, as stated by Rangarajan, a combination of column and

benthic feeding habits of L. kasmira in Andaman Islands could have provided access to prey that was both pelagic and benthic in origin, while demersal food items in specimens of Lakshadweep is suggestive of a benthic carnivorous habit. However, among lutjanids in Lakshadweep, L. kasmira had a higher feeding diversity (H' = 1.93).

Malacanthidae: As no previous reports on the feeding habits of Melacanthus lattovittatus could be obtained, it has been classified as an omnivore based on its food habits.

Mugilidae: Gut contents of Crenemugil crenilabis from Marshall Islands consisted detritus and sand followed by a variety of algae (Hiatt and Strasburg, 1960). Green algae dominated the diet in specimens examined in Lakshadweep while the invertebrate fauna could have gained entry due to their association with algae.

Mugiloididae: Food preference of Parapercis hexophthalma suggests that this species is a benthic carnivore.

Mullidae: Crabs, shrimp and polychaetes dominated the gut contents of Mulloides flavolineatus in Lakshadweep, indicating that it was a benthic carnivore, as expected from all members of this family. Sorden (1982) reported polychaetes to be the most important food item of M. flavolineatus in Hawaii. Relatively low H' values (1.52 and 1.87) in Parupeneus cyclostomus and P. barberinus is perhaps due to their preference for specific food items; fish in the former and polychaetes in the latter. Fish in the guts of P. cyclostomus was reported by Hiatt and Strasburg

(1960) and Hobson (1974). However, significant amounts of shrimp were also found in specimens from Lakshadweep. (the specimen recognized as P. chryserydros by Hobson could perhaps be P. cyclostomus) Fischer and Bianchi, 1984). Food preferences of P. barberinus examined by Hobson (1974) were similar to those in the present study. Further, Hobson reported xanthid crabs, fish, crab megalopae and caridean shrimps as dominant food items in P. bifasciatus which is also in accordance with food items observed in the present study. However, polychaetes and small fish were not reported. P. macronema and P. pleurostigma shared similar diets, but the greater feeding diversity (H' = 2.12) in the latter was due to significant proportions of pelecypods and occasional sea urchin remains. Hiatt and Strasburg (1960) stated that mullids in general avoid hard bodied forms (molluscs and echinoids) as they lack crushing dentition, and this was reflected by the absence of such food items or low proportions in the present study. However, data suggest that P. pleurostigma intentionally consumes pelecypods.

Plesiopidae: Plesiops caerulolineatus was mainly collected at night owing to their nocturnal habit. This species is commonly found among coral debris or rubble and is a carnivore. Except for feeding on polychaetes, its diet was similar to that of P. melas and P. nigricans reported by Hiatt and Strasburg (1960), where crustaceans (crabs and shrimps) and fish were the main prey items.

Pomacanthidae: Centropyge multispinis showed feeding habits similar to pomacentrids of the genus Dascyllus in that it fed mainly on zooplankton.

Hiatt and Strasburg (1960) reported C. flavissimus to be a herbivore. However, this species appears to feed both on animal and plant matter and could be termed as an omnivore.

Pomacentridae: A ~~wide~~ wide range of diets observed in pomacentrids kept H' values high (2.00 and above) except in C. dimidiata where it was 1.92 possibly due to preference of only few food items. The lowest H' value (1.48 and 1.72) in Amphiprion chrysogaster and A. nigripes is possibly due to their association with amenones and which results in a narrow home range, limiting access to a wide range of prey. However, these anemonefishes seemed efficient in capturing fish larvae which formed a major diet component. Though Abudefduf sexfasciatus was a zooplanktivore, data indicated that it preferred larger zooplankton and a slight tendency towards herbivory was also noticed. Algae and crustaceans in nearly equal proportions, were found in related species, namely, A. sordidus, A. septemfasciatus and S. saxatilis (Hiatt and Strasburg, 1960). A similar observation was made by Emery (1973) for A. saxatilis. Observations of Madan Mohan et al. (1986) on food habits of Chromis caerulea from Minicoy atoll were similar to those found in the same species from Kavaratti atoll. Zooplanktivory in the genus Chromis was reported by Emery (1973), Bray (1981), Bray et al.,(1981) Tribble and Nishikawa, (1982) Choat, 1991). Hiatt and Strasburg (1960) mentioned the dominant diet of C. caerulea to be their own eggs and calanoid and cyclopoid copepods. Eggs were also found in the present study but in low proportions. C. dimidiata showed a similar diet. Despite consuming a wide range of food items, copepods and fish larvae were dominant.

Species of the genus Pomacentrus and Chrysiptera are omnivores. However, within the latter group, a number of species have pronounced tendencies towards herbivory (Choat, 1991). This is supported by observations on the diets and H' values (2.44 and 2.70) of Chrysiptera glauca and C. unimaculata which contained equal proportions of zooplankton and algae.

Species of the genus Dascyllus are aggregating planktivores (Hobson 1974; Choat, 1991). Dascyllus aruanus mainly consumed copepods, fish eggs and polychaete fragments (Hiatt and Strasburg, 1960) while diets including copepods, amphipods, filamentous algae and coralline material were observed by Pillai et al. (1987). A H' of 2.26 in the present study coupled with data on prey items indicated a greater feeding diversity, apart from the preferred food items reported in previous studies. D. reticulatus registered a high H' value of 3.07 perhaps due to consumption of similar prey items with relatively even proportions. The most dominant prey items for this species were reported to be copepods, polychaete larvae and decapod larvae (Vijay Anand, 1990 a), while in the present study apart from copepods, fish larvae and eggs were found to be the dominant prey items. Fish larvae and eggs were probably overweighed due to coincidence of fish collections and spawning seasons of other fish and invertebrates or differences in collection areas. Regional differences of zooplankton occurring on coral reefs is a well documented phenomenon (Bakus, 1964; Hourigan, 1989) and on Kavaratti atoll (Madhu Pratap et al., 1977). D. trimaculatus had similar food preferences as those of D. reticulatus.

The genus, Pomacentrus has also been included in the omnivore category (Choat, 1991). Specimens examined by Hiatt and Strasburg (1960) mainly contained fish and crustaceans and was termed as a carnivore. In the present study, though algae formed the major food of Pomacentrus pavo, it also preyed upon benthic invertebrates and retained its identity as an omnivore. A similar feeding habit was reported in Abudefduf glaucus from Minicoy atoll, Lakshadweep by Pillai and Madam Mohan (1990).

The most explicit herbivorous members of the Pomacentridae are the large territorial species of the genera Plectroglyphidodon, Stegastes and two other genera (Choat, 1991). Observations on food preferences of Plectroglyphidodon phoenixensis, Stegastes lividus and S. nigricans indicate higher consumption of algae. However, representation of other food items could be due to consumption of organisms present in the respective territories of these herbivores. The 'resident' or 'demersal' meroplankton includes not only larval or pelagic juvenile forms, but all other planktonic animals that are either in the plankton only briefly or that have a benthic habit during part of the day (Parrish, 1987). Stegastes lividus in Guam shifted from omnivory as juveniles to herbivory as adults (Lassuy, 1984).

Scaridae: Scarids were considered as coral feeders (Hiatt and Strasburg, 1960; Talbot, 1965) but subsequent workers reported scarids to be herbivores (Randall, 1965, 1967; Hobson, 1974; Russ, 1984 b; Thayer et al., 1984). In the present study, the five scarid species examined did not show marked differences in the algal food consumed. An insignificant

proportion of crustaceans would have gained entry with algal food while most of the semidigested matter consisted of sediment of calcareous origin. No evidence on coral feeding was derived. Hobson (1974) reported Scarus rubroviolaceus and S. sordidus to scrape benthic algae from rock surfaces.

Scorpaenidae: Parrish et al. (1986) mentioned Scorpaenidae as one among many families producing the largest piscivorous impacts. In the present study, small fish and crabs formed dominant prey items. Dendrochirus zebra mainly fed on brachyuran crabs (81.90%) and shrimp (17.40%) (Harmelin-Vivien and Bouchon 1976). As most of the gut contents were in a digested condition, during the present study, definite conclusions could not be drawn. However, results were grossly similar to previous observations. A low H' could have resulted due to insignificant representation of prey items. Pterois antennata fed mainly on shrimp (65.20%) and galatheids (34.80%) (Harmelin-Vivien and Bouchon, 1976) while in the present study, they consumed only fish and crabs. P. miles showed a high H' value (2.43) as it consumed a greater variety of prey items. P. radiata consumed mainly fish while Hiatt and Strasburg (1960) found that this species fed only on crustaceans, especially xanthid crabs.

Serranidae: Dominant prey of Cephalopholis argus was fish and cephalopods. Hiatt and Strasburg (1960) observed crustaceans and fish in its diet while Randall and Brock (1960) found that 77.50% of stomachs examined contained fish and the rest were crustaceans (shrimp , crabs and stomatopods). The dominance of fish was also reported by Hobson (1974) and Harmelin-Vivien and Bouchon (1976). In the case of Epinephelus hexagonatus, crabs were most dominant unlike in other reports where fish

was reported to be the dominant prey. Various prey items reported for this species were fish and polychaetes (Hiatt and Strasburg, 1960), fish and crabs in equal proportions (Randall and Brock, 1960), fish (74.10%) and stomatopods (21.50%) (Harmelin-Vivien and Bouchon, 1976). E. tauvina showed a piscivorous tendency.

Siganidae: Seagrasses, other algae and algal fronds formed dominant food items in Siganus argenteus and S. stellatus. Hiatt and Strasburg (1960) reported S. rostratus to be a grazer on filamentous algae. Tsuda and Bryan (1973) observed that huge invasions by S. rostratus and S. spinus depleted green algae rapidly in Guam.

Tetraodontidae: Shrimp, small crabs and gastropods formed the main prey items in Canthigaster margaritata and C. valentini. Hiatt and Strasburg (1960) stated that the predominant food item taken by C. solandri was algae but the animal composition in their diets was sufficient to designate it as an omnivore. In two other species studied by Hobson (1974) they were found to consume coralline algae and various hard-bodied invertebrates. Hiatt and Strasburg (1960) observed Tetraodon nigropunctatus predominantly consuming living tips of Acropora spp. as food but is also known to take crustaceans and molluscs. In the present study, only gastropods were found in the gut contents. T. hispidus preys on a variety of hard shelled benthic invertebrates (Hiatt and Strasburg, 1960; Hobson, 1974) but in the present study, only crabs and gastropods were observed.

Zanclidae: Zanclus canescens fed on algae, sponges and bryozoans in Lakshadweep. Hobson (1974) reported that this species in Hawaii mainly fed on sponges.

Food and feeding habits of coral reef fishes from the Gulf of Mannar region.

Acanthuridae: Food habits of Acanthurus dussumieri from Gulf of Mannar were similar to those examined in Lakshadweep. However, filamentous algae were dominant in the former with brown algae and crustaceans as additional items which elevated its feeding diversity (1.99) as compared to 1.45 in Lakshadweep. Jones (1968) reported that this species consumed detritus, diatoms and filamentous algae in Hawaii.

Chaetodontidae: Chaetodon auriga showed a marked change in food habits between the two geographical regions. The most dominant food items for this species in Lakshadweep were coral polyps and polychaete tentacles while in Gulf of Mannar its major diet was filamentous algae; coral polyps were secondary in importance. Feeding diversity of C. auriga in Gulf of Mannar (1.94) compared closely to 1.60 given by Sano (1989) and 1.73 given by Harmelin-Vivien (1989). Observations from this region strongly support its identity as a general omnivore categorised by Burgess (1978). The difference could perhaps be due to variation in the reef systems - which in turn might harbour different forgae bases. C. collare was found to be the most abundant chaetodontid in this region with its food preferences, the same as in specimens of Lakshadweep. However, a high H' value indicated a greater diversity in feeding niche. C. octofasciatus

was next to C. collare in abundance and preferred algae as its main food. The abundance and feeding preferences in these two species evokes curiosity on the possible cause for this pattern. C. collare was rare in Lakshadweep while C. octofasciatus was totally absent. It is possible that their successful flourishing on Gulf of Mannar reefs could be due to some desirable species of algae that form food. Coral polyps were conspiciously absent in their diets.

The typical coral feeding fishes, Chaetodon trifascialis and C. trifasciatus showed a coral feeding tendency in Gulf of Mannar region and support the findings of Hiatt and Strasburg (1960), Anderson et al (1981), Reese (1981), Harmelin - Vivien and Bouchon - Navaro (1983), Harmelin - Vivien (1989), Irons (1989) and Sano (1989). H' values were similar but for 2.13 recorded by C. trifasciatus due to a variety of food items consumed. Similar observations were made for these species in Lakshadweep. Apart from these two species C. plebeius and C. decussatus also showed coral feeding tendencies, but could also resort to feeding on algae. It is evident that the number of chaetodontids feeding on corals in Gulf of Mannar was roughly comparable to that in Lakshadweep, indicating that coral health is comparable in both regions despite large scale coral mining that existed in the Gulf of Mannar. However, the establishment of marine park areas has stopped coral mining possibly helping in regaining reef health, thus reflecting in the diets of chaetodontids. Reese (1981) stated that fish being motile may provide an early warning to deteriorating conditions by changes in their behaviour, including eventual movement away

from the reef. Therefore a time-series study on such chaetodontids may provide good feed back on the effectiveness of conservational methods employed.

Unlike the specimens of C. lunula in Lakshadweep, the Gulf of Mannar individuals did not feed on either coral polyps or polychaete tentacles, but consumed benthic invertebrates and algae. These observations were similar to findings of Hobson (1974) who found benthic invertebrates preyed upon at night and Sano (1989) who termed this species as a non-coralline invertebrate feeder. Harmelin - Vivien (1989) found that scleractinian corals formed 55.70% of the stomach contents. Based on observations in the present study and previous reports, this species appears to have a flexible diet, perhaps dependent on local biotope. H' of specimens examined from both the regions indicated values above 2.00 as compared to 0.62 (Harmelin-Vivien, 1989) and 0.65 (Sano, 1989). This difference could be due to variation in the number of prey items involved in their respective diets or different calculation procedures.

Food preferences of Chaetodon melannotus were roughly similar between specimens collected from the two geographically different areas. Filamentous algae dominated food items of C. melannotus in Gulf of Mannar, followed by polychaete tentacles and their positions were inter-changed in Lakshadweep where polychaete tentacles dominated the diets. As indicated by H' values, feeding preferences varied perhaps in the number and quantity of food items consumed. Though insignificant, the Gulf of Mannar specimens showed slight tendency towards coral feeding. Therefore,

reports stating that they are coral feeders (Talbot, 1965) and their association with live coral cover (Adrim and Hutomo, 1989) can only be remotely supported by the present study. C. oxycephalus restricted itself to benthic invertebrates and algae. C. xanthocephalus of Gulf of Mannar differed from specimens in Lakshadweep in not having filamentous algae as their major food items. Though coral polyps were recorded, their proportion did not reflect a coral feeding habit. Talbot (1965) categorised this species as coral feeder. Observations here are almost in accordance with those of Harmelin-Vivien (1989) who found ascidians and polychaetes to constitute 80.00% of the diet; this could also have lowered the H' in her report (1.58) as compared to 1.88 in the present study.

Haemulidae: The three species of haemulids from Gulf of Mannar had similar diet preferences as compared to two different species occurring in Lakshadweep; fish and crabs being the most dominant prey items.

Holocentridae: The five species of the genus Sargocentron from Lakshadweep clearly indicated their dependence on benthic invertebrates and small fish. Similar observations were made in Sargocentron rubrum from Gulf of Mannar except for feeding on large copepods, whose presence indicates off-bottom feeding. This could have also been aided by the nature of fringing reefs that face open waters carrying zooplankton. The planktonic mode of feeding in Myripristis murdjan from both localities was same excepting that dominant prey zooplankton varied possibly due to regional differences in zooplankton composition. Decapod larvae dominated the prey of M. murdjan in Lakshadweep while this was replaced by copepods in Gulf of Mannar. H' was slightly higher in the latter case due to an even preference of prey items.

Labridae: Fischer and Bianchi (1984) mentioned that molluscs, crustaceans and seaurchins formed diet components of C. undulatus. Food preferences of this species from Gulf of Mannar and Lakshadweep were similar excepting that crustaceans were more dominant than molluscs. This is perhaps due to differences in regional prey compsition. A higher H' value was due to consumption of a wider variety of prey. A similar trend and reasoning in H' of Hemigymnus melapterus was evident. Diets from the two localities for this species were similar but with changes in relative importance between crabs and stomatopods. Seaurchin remains recorded in H. melapterus from Lakshadweep were replaced by shrimp in Gulf of Mannar. Food preferences of Thalassoma lunare from Gulf of Mannar were entirely different from those of Lakshadweep in the sense that molluscs and crustaceans were dominant as compared to eggs, polychaetes and fish. This could be attributed only to possible local changes occurring in the biotope. H. dussumieri consumed only stomatopods and crabs. An overall picture on labrid prey from the two localities suggest that crabs were common food items but stomatopods consumed in the Gulf of Mannar region were substituted by a variety of other molluscs, echinoderm remains and crustaceans (other than crabs).

Lutjanidae: Fish and crabs formed important prey of lutjanids from Lakshadweep and a similar trend was observed in lutjanids from Gulf of Mannar.

Pomacentridae: The differences in the food of Abudefduf sexfasciatus between the two localities is perhaps due to a wider range of zooplankton and algae present in Lakshadweep as compared to Gulf of Mannar reefs. This is also reflected in higher H' values in Lakshadweep. Copepods and

decapod larvae in the latter were replaced by shrimp, megalopae, green algae and fish. With the total absence of algae in its guts, it could be termed as a zooplanktivore. This difference is possibly due to lack of extensive shallow reef areas that could support algae on steep fringing reefs while on the other hand, an easier access to open water zooplankton is provided. As expected of the genus Chromis, C. ternatensis emerged as a true zooplanktivore.

In comparing the commonly occurring species between the two localities, it was found that prey items in general appeared to be few in the Gulf of Mannar region as compared to Lakshadweep. This is perhaps due to the nature of reef formation or the type of substratum offered for a variety of prey items. Differences in prey preferences of the same species from two different localities could arise due to this reason. Harmelin-Vivien and Bouchon (1976) stated that ubiquitous species adjust their diet to the food available, therefore prey consumption differs according to biotope.

To comment on the overall picture of trophic levels in coral reef fishes, the whole fauna has to be considered. Such an attempt is not made in the present study as it is based on only common reef fishes. It is evident from the present study that certain families have exclusively herbivorous species (Acanthuridae, Kyphosidae, Scaridae and Siganidae) while most of the other families cannot be strictly grouped as zooplanktivores, omnivores, benthic carnivores or carnivores owing to high overlap in food preferences. Though apogonids are considered predominantly zooplanktivores, they fed on benthic invertebrates. Among

omnivores, the variation in plant and animal matter proportion could stem a particular species more towards herbivory or carnivory while an equilibrium status could retain its identity as an omnivore. Mullids can be ideal examples of benthic carnivores, while certain holocentrids (Neoniphon and Sargocentron) showed piscivorous tendency.

Certain changes observed in strict corallivorous chaetodontid species alter the title 'obligate coral feeders' to be transformed to any other suitable category. Species regarded as strict piscivores were observed to feed directly on lower or intermediate trophic levels containing invertebrates. With these few examples the plasticity in feeing habits of reef fishes is evident and this is one reason which perhaps permits the coexistence of wide variety of fishes, all of which depend on definite food resources.

CHAPTER V

REPRODUCTION

CHAPTER V

REPRODUCTION

INTRODUCTION

Reproductive strategies of coral reef fishes are diverse and not well known (Smith, 1982). They tend to be highly fecund species which produce eggs that vary greatly in number from tens to hundreds to thousands at a time, on a daily, weekly, fortnightly, monthly or less frequent schedules (Sale, 1991 a). Sale further recognized that reef fish are also flexible in how they determine sex. In addition to the conventional gonochoristic species in which the sex of individuals is fixed, there are numerous hermaphroditic species. Some of these are simultaneous hermaphrodites, most of them are sequential hermaphrodites, and in being so, a majority of the species are protogynous (female first, then male) while few are protandrous. Most reef fishes lay pelagic eggs although some lay demersal eggs with parental care, some are oral or mouth brooders and some are viviparous (Smith, 1982).

Once they hatch, most of them undergo two distinct phases in their life cycle, a pelagic larval phase followed by a reef resident phase in the

parental habitat (Johannes, 1978; Sale, 1980 a) where they grow and change habitats within a reef system to suit their adult life. Enormous information on the reproduction and recruitment of coral reef fishes exists world-over. Though extensive reef systems exist in the Indian EEZ, the basic life cycles and other aspects of biology and ecology have received the least attention. The present study therefore attempts to make a beginning in the documentation of certain aspects of the reproductive biology of 25 commonly occurring coral reef fishes from Lakshadweep and Gulf of Mannar region. Further, a short-term investigation on the juvenile coral reef fishes settling on to seagrass beds has been undertaken to highlight the role of seagrass beds that act as nurseries.

REVIEW OF LITERATURE

The few studies on aspects of the reproductive biology of coral reef fishes in India are those of Rangarajan (1971) dealing with maturity andspawning of Lutjanus kasmira (Forsskål) from the Andaman sea, Pillai et al. (1984) discussed about an unusual massive recruitment of the reef fish Ctenochaetus strigosus to the Minicoy atoll and its significance. The three pomacentrid species studied for their development of gonads, fecundity, size at maturity, sex-ratio, maturity and spawning seasons were Dascyllus aruanus (Pillai et al., 1987), Chromis caeruleus (Madan Mohan et al. 1986) Abudefduf glaucus (Pillai and Madan Mohan, 1990) from Minicoy atoll, Lakshadweep and Chaetodon auriga, Halichoeres centiquadrus and Dascyllus reticulatus (Vijay Anand and Varghese, 1992 a) from Kavaratti atoll, Lakshadweep.

Reef fish vary greatly in where, when and how they reproduce (Sale, 1991 a). Most coral reef fishes undergo two distinct phases in their life cycle, a pelagic phase and a reef resident phase (Johannes, 1978; Sale 1980 a). Spawning seasons of 73 species of East African reef fishes were found to occur throughout the year with some peaks (Nzioka, 1979). Coral fishes have been selected to produce propagules (eggs) for dispersal because they live in a patchy environment (Barlow, 1981). Colin (1982) studied 30 species of fish for their spawning habits from Puerto Rico and discussed various modes of reproduction in western Atlantic reef fishes. Smith (1982) studied the patterns of reproduction in coral reef fishes while Thresher (1982) compared aspects of spawning of coral reef fishes of the tropical western Atlantic and Western Pacific. Doherty and Williams (1988) outlined three models of the ecological processes contributing to the replinishment of populations of coral reef fishes and reviewed the evidence supporting each of them. Robertson (1991) stated that variations in reproductive behaviour respond to selective force acting on adult fishes. The differential availability of pre-settlement fish and habitat selection contributed to the differences in recruitment of Chaetodon rainfordi found between the northern and southern regions of the Greater Barrier Reef (Fowler et al., 1992).

Various families of Caribbean coral reef fishes studied for aspects of their biology, ecology and bionomics are Balistidae (Aiken, 1983); Mullidae (Munro, (1983); Acanthuridae (Reeson, 1983); Lutjanidae, (Thompson and Munro, 1983); Holocentridae (Wyatt, 1983). Studies on the spawning behaviours of surgeonfishes (Acanthuridae) from the Society

Islands were made by Randall (1961) and from the Indo-Pacific region by Robertson (1983). Few aspects of reproductive biology were dealt by Ferreira de Menzes (1979) in a study on the biology and biometry of triggerfishes of northwest Brazil. Modes of reproduction in goatfishes (Mullidae) were dealth by Munro (1976) while Colin and Clavijo (1978) reported on the mass spawning of Pseudupeneus maculatus.

Tribble (1982) reported that Coris dorsomaculata was sexually dichoromatic and males arise from sex changed females, at Miyake-jima, Japan. Sex change in Thalassoma lucasanum is a relatively rare event; fewer than 30% of the terminal phase individuals are derived from females and the initial phase populations consist of nearly 50% primary males (Warner, 1982). Mating in Thalassoma duperrey is a daily event during the reproductive season (Ross, 1985). Schultz (1985) dealt with the life history strategies of female Thalassoma bifasciatum.

Chaetodontids have been extensively studied for their reproductive biology. Studies on Chaetodon miliaris from Hawaii dealt with anomalous growth and reproductive patterns (Ralston, 1976) and aspects of the reproductive biology and feeding ecology (Ralston, 1981). Burgess (1978) mentioned about a few aspects of chaetodontid reproduction in his study on the butterflyfishes of the world. Walsh (1987) found lunar periodicity in Chaetodon multicinctus from Hawaii and their recruitment to be greatest in summer. Aspects of spawning of western Atlantic butterflyfishes were dealt by Colin (1989) while Lobel (1989) conducted a similar study on C. multicinctus.

Pomacentridae is a group which has been widely studied for their spawning and recruitment. In describing various modes of reproduction in fishes, Charles and Don (1966) gave an account on reproduction of pomacentrids. Observations on spawning/reproduction of Chromis multilineata were described by Myrberg et al., (1967). Deposition of eggs of Chromis caeruleus on algal mats was observed by Swerdloff (1970). Pressley (1980) found that reproductive activity was the highest in the time periods from full to new moon for Microspathodon chrysurus. Males and females of Chromis notata repeated reproductive cycles many times during the breeding season (Ochi, 1985). Seasonal and environmental stresses on adults affect the structure of the spawning cycle (Robertson, 1990).

Virtually all reef fishes undergo a profound transition from life as larvae adrift in the oceanic plankton to a settled existence closely associated with the coral reef structure (Victor, 1991). Juveniles and sub-adults were generally more abundant in shallow water areas whether it be coral reefs or seagrass beds (Fricke, 1973). Leis and Muller (1976) studied the offshore distributional patterns of Hawaiian fish larvae. Seagrass beds contain juveniles of several species that occur in the adult fauna of neighbouring reefs (Ogden and Zieman, 1977). Among the 19 groups of fauna and flora associated with seagrass beds Den Hartog (1979) categorised juvenile life on the habitat as a temperorary phenomena. Weinstein and Heck (1979) dealt with aspects of juvenile ichthyofauna on seagrass meadows along the Caribbean coast and in the Gulf of Mexico. In studies on the spatial and temporal patterns of recruitment of juvenile

coral reef fishes to coral habitats within "One tree lagoon" Great Barrier Reef, Williams and Sale (1981) found seasonal variations in abundance of juveniles. Immigration of planktonic larvae of fishes to coral reefs is a predominant mechanism of recruitment for most sedentary reef fishes (Robertson and Foster, 1982) while Doherty (1983) implicated larval abundance as the major determinant of community structure in benthic populations of coral reef fishes. Recruitment of juveniles significantly decreased in the presence of adult territorial damselfishes (Shulman et al., 1983). The choice of micro-habitats by coral reef fishes at settlement was studied by Sale et al. (1984). While food did not influence settlement, availability of refuges from predation was an important factor in determining population sizes (Shulman, 1984). Eckert (1985) stated that habitat has a large influence on settlement.

Juveniles settling in the seagrass beds/algae remain there only for a short period of time and migrate to nearby reefs as they get older (Shulman, 1985 a). Schooling species showed clumped, highly variable recruitment while non-schooling species showed random, less variable recruitment patterns (Shulman, 1985 b). Most types of larvae preferred deeper waters ($>$ 3 m) during day and moved upward at night (Leis, 1986). Abundance of juveniles in isolated artificial seagrass units (ASU's) were primarily due to availability of larvae prepared to settle indiscriminately into any shelter and not due to physical complexity of the habitat (Bell et al., 1987). Variability in assemblages at different sites on and around an island could be due to currents that are less favourable for retention of larvae (Leis and Goldman, 1987) and those settling in sand

or seagrass usually migrate to reefs before they are one month old (Shulman and Ogden, 1987). Victor (1987) found that labrid larvae had longer larval lives than pomacentrid larvae. Timing and magnitude of settlement are strongly influenced by both production and planktonic processes (Robertson et al., 1988). Seagrasses provide shelter and food during the early life history stages when individuals are susceptable to predation (Bell and Pollard, 1989). The existing knowledge on the larval biology of butterflyfishes was summed up by Jeffrey (1989).

In some recent reviews, Victor (1991) dealt with settlement strageties and biogeography of reef fishes; Doherty (1991) dealt with spatial and temporal patterns in recruitment and Jones (1991) dealt with post recruitment processes in the ecology of coral reef fish populations. Temporal variation in recruitment occurs only at nearshore stations while on the outer fringing reef and inner barrier reef, recruitment patterns were stable (Planes et al., 1993).

MATERIAL AND METHODS

Twenty five commonly occurring species were selected mainly from Lakshadweep and few from Gulf of Mannar region to study aspects of maturity and spawning during the period January 1991 to June 1992.

A. Maturity and spawning: Five maturity stages, namely, immature, maturing, mature, ripe and spent were recognized based on macroscopic and microscopic examination of gonads for use in determining the size at first

maturity. Sex, gonad weight, stage of maturity and the standard length of individual fishes were recorded. To determine the size at first maturity, two broad categories were formed to designate immature (immature + maturing) and mature specimens (mature + ripe). Percentages tabulated against size groups indicated the minimum size at which mature fish occurred for the first time. Sex-ratio was computed based on total number of females and males recorded and the ratio expressed as female : male.

Fecundity was estimated by counting mature ova from preserved, ripe ovaries.

To determine the spawning frequencies, diameters of intra-ovarian eggs from preserved ovaries were measured by means of an occular micrometer with a magnification of 0.032 mm to each division. Ova were measured at random and frequency polygons drawn. Percentage occurrence of ripe and spent specimens on a monthly time scale were used to determine the spawning seasons.

B. Occurrence of juveniles on seagrass beds: As little is known about the early life histories of reef fishes from India, a study based on nocturnal collections of juveniles belonging to 28 families from seagrass beds was undertaken. Collections were made for a 2- month period using a velon screen 10 m wide and 2 m high on a towing length of 25 m.

To determine the relative importance of juveniles belonging to each family, monthly data were pooled to obtain total abundance and its percentage during the study period. Total number of juveniles recorded in each monthly sample was used to study the monthly fluctuations in the

occurrences of juveniles on seagrass beds. Based on underwater observations and catch data, the important processes occurring on seagrass beds were described and discussed.

Salinity was analysied on a monthly basis using standard methods (Strickland and Parson, 1972) while temperature was recorded on the spot during nocturnal collections. Rank correlation was used to test juvenile abundances against salinity and temperature. The same in relation to moon phases was tested using ANOVA (Bakus, 1990).

RESULTS

A. MATURITY AND SPAWNING

Size at first maturity, sex-ratio, fecundity, spawning frequency and spawning seasons of 25 commonly occurring species are dealt in this section.

1. Acanthurus leucosternon: 148 individuals were examined. Sex of 18 nos. was indeterminate occurring in size ranges between 61 to 90 mm. Immature females were observed in the size range of 81 to 90 mm. 65 female fishes were recorded. All fishes measuring between 81 to 100 mm were immature. Size at first maturity was between 101 to 110 mm where the proportion of mature and immature fish was 62.50% and 37.50% respectively. Few immature fish (16.00%) and mature fish (84.00%) were recorded in the size group, 111 to 120 mm. All females examined above 121 mm were mature.

65 male fishes were examined. Individuals measuring between 81 to 100 mm were immature. Mature males occurred between 101 to 110 mm with proportions of mature and immature fish being 16.67% and 83.33% respectively. Size at which males appeared to mature was between 111 to 120 mm. All individuals recorded above 111 mm were mature fish (Table 42). Sex ratio for A. leucosternon was 1:1, while the fecundity range was 19004 to 25603 eggs per female fish.

Three groups of ova with modes at 0.29, 0.42 and 0.67 mm were noticed. The species appears to spawn continuously as the successive modes are not distinctly separated from one another. The maximum size of ova was 0.67 (Fig 47 A).

Spawning individuals occurred from January '91 to June '91 and September '91 to April '92. Higher proportions were observed in February (80.50%), April (75.00%), June (75.00%), March (75.00%) and April '92 (83.33%). In general mature fishes were recorded from September to April, while they were not recorded in May, July and August (Table 67, Fig 50 A).

2. Acanthurus triostegus: 216 individuals were examined, Indeterminate fishes (47 nos) occurred between 21 to 70 mm. 93 females were recorded. Immature fish occurred between 71 to 80 mm. Mature and immature females (25.00 and 75.00% respectively) were recorded between 81 to 90 mm. Females measuring above 100 mm were mature.

76 male fishes were recorded. All fishes between 61 to 70 mm were immature. Size at first maturity for males was between 71 to 80 mm. Proportions of mature males in the size groups 71 to 80 mm, 81 to 90 mm and 91 to 100 mm were relatively high (86.67, 64.30 and 92.00% respectively) while immature males continued to occur in low proportions (13.33, 35.70 and 8.00% respectively). Individuals above 101 mm were mature (Table 43). Sex ratio of A. triostegus was 1:0.82 while the fecundity range was 10963 to 20400.

Ova diameter frequency polygon of A. triostegus indicates three modes at 0.42, 0.54 and 0.67 mm. Immature stock of ova appear to be separated from the mature stock although the larger ova forming three groups were not distinctly separated from each other. The species may spawn continuously with a likely break after all mature ova are shed. The maximum size of ova was 0.74 (Fig 47 B).

Spawning fish occurred in three distinct time scales, February to May '91 (41.67, 62.50, 55.56 and 60.00% respectively), November and December (69.23 and 50.00%) and February to May '92 (36.84, 70.00, 18.52, and 50.00%) respectively. Few individuals were also observed in September '91 accounting for 31.25%. Spawning of individuals was observed from November to May (Table 67, Fig 50 B).

3. Chaetodon collare: 185 individuals were examined. Indeterminate fishes (106 nos) occurred between 31 and 90 mm. 53 females were recorded. Sex could be determined in the size group, 81 to 90 mm

Tables 42 & 43. Size at first maturity for females and males of A. leucosternon and A. triostegus (values in percent against size).

Table 42 Acanthurus leucosternon			Females		Males		
Size (mm)	IND	NF	I	M	NM	I	M
61 - 70	6	-	-	-	-	-	-
71 - 80	4	-	-	-	-	-	-
81 - 90	8	2	100.00	-	4	100.00	-
91 - 100	-	6	100.00	-	4	100.00	-
101 - 110	-	8	37.50	62.50	12	83.33	16.67
111 - 120	-	25	16.00	84.00	14	-	100.00
121 - 130	-	15	-	100.00	18	-	100.00
131 - 140	-	3	-	100.00	--	-	--
141 - 150	-	3	-	100.00	1	-	100.00
151 - 160	-	3	-	100.00	12	-	100.00
	18	65			65		

Table 43 Acanthurus triostegus			Females		Males		
Size (mm)	IND	NF	I	M	NM	I	M
21 - 30	11	-	-	-	-	-	-
31 - 40	9	-	-	-	-	-	-
41 - 50	9	-	-	-	-	-	-
51 - 60	7	-	-	-	-	-	-
61 - 70	11	-	-	-	9	100.00	-
71 - 80	-	14	100.00	-	15	13.33	86.67
81 - 90	-	8	75.00	25.00	14	35.70	64.30
91 - 100	-	23	-	100.00	25	8.00	92.00
101 - 110	-	25	-	100.00	13	-	100.00
111 - 120	-	20	-	100.00	-	-	-
121 - 130	-	3	-	100.00	-	-	-
	47	93			76		

IND - Indeterminate, NF - Number of females, NM - Number of males, I - Immature, M - Mature.

where all individuals were immature. Females matured first between 91 and 100 mm where 75.00% of fish were mature while 25.00% were immature. Fully mature individuals occurred above 101 mm.

26 males were recorded. Fish recorded between 81 to 100 mm were immature. 89.90% of mature males measured 101 to 110 mm which was the size at first maturity for males. Fully mature individuals measured above 111 mm (Table 44). Sex-ratio of C. collare was 1:0.49 while the fecundity range was 2763 to 31065. Samples were collected from the Gulf of Mannar region (Keelakkarai group of Islands).

Four modes of ova are evident in the ova diameter polygon, the modes not distinctly separated. The species is likely to spawn continuously. The maximum size of ova was 0.93 (Fig 47 C).

Higher proportions of spawning fishes were observed in April '91 (40.00%), February and March '92 (28.57 and 56.25% respectively). Except during June, July, October and November, mature individuals continuously occurred (Table 67, Fig 50 C).

4. Chaetodon melannotus: 188 individuals were examined. Indeterminate fishes (76 nos) occurred between 41 and 80 mm. 57 females were recorded. Fishes measuring between 61 and 70 mm were immature. Size at first maturity for females was between 71 and 80 mm with proportions of mature and immature females' being 25.00 and 75.00% respectively. A greater proportion (56.25%) of females were mature between 81 and 90 mm while immature females formed 43.75%. Fish measuring above 91 mm were fully mature.

55 males were recorded. Fish measuring below 70 mm were immature. Males matured first between 71 and 80 mm accounting for 21.40% of mature fish and 78.60% of immature fish. A greater proportion of males (57.10%) were mature between 81 to 90 mm while 42.90% were immature. Fishes measuring above 91 mm were fully mature (Table 45). Sex - ratio of C. melannotus was 1:0.96, while the fecundity range was 1492 to 24532. All individuals were collected from the Gulf of Mannar region (Keelakkarai group of islands).

The ova diameter frequency polygon exhibits three distinct modes at 0.22, 0.48 and 0.86 mm which are distinctly separated from one another. The species appears to be a continuous spawner with breaks in the spawning activity. The largest ova measured 0.93mm (Fig 47 D).

Spawning fishes occurred in greater proportions in February, March and April '91 (66.67, 46.15 and 26.67% respectively), September '91 (30.77%), January '92 (66.67%) and March and April '92 (62.50 and 58.33% respectively). Mature fish were not observed in May, June, July and December. In general, they occurred from August to May (Table 67, Fig 50 D).

5. Chaetodon octofasciatus: 194 individuals were examined. Indeterminate fishes (75 nos) occurred between 41 to 80 mm. 45 females were recorded. Sex was identified between 61 to 70 mm. Size at first maturity for females was between 71 to 80 mm, proportions of mature and immature individuals being 60.00 and 40.00% respectively. Fishes measuring above 81 mm were fully mature.

Tables 44 & 45. Size at first maturity for females and males of C. collare and C. melannotus (values in percent against size).

Table 44	Chaetodon collare			Female	Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 40	21	-	-	-	-	-	-
41 - 50	13	-	-	-	-	-	-
51 - 60	24	-	-	-	-	-	-
61 - 70	13	-	-	-	-	-	-
71 - 80	23	-	-	-	-	-	-
81 - 90	12	18	100.00	-	5	100.00	-
91 - 100	-	8	25.00	75.00	2	100.00	-
101 - 110	-	11	-	100.00	9	11.90	89.90
111 - 120	-	6	-	100.00	3	-	100.00
121 - 130	-	-	-	-	-	-	-
131 - 140	-	10	-	100.00	7	-	100.00
	106	53			26		

Table 45	Chaetodon melannotus			Females	Males		
Size (mm)	IND	NF	I	M	NM	I	M
41 - 50	15	-	-	-	-	-	-
51 - 60	10	-	-	-	-	-	-
61 - 70	13	5	100.00	-	6	100.00	-
71 - 80	38	16	75.00	25.00	14	78.60	21.40
81 - 90	-	16	43.75	56.25	7	42.90	57.10
91 - 100	-	8	-	100.00	14	-	100.00
101 - 110	-	12	-	100.00	14	-	100.00
	76	57			55		

IND - Indeterminate, NF - Number of females, NM - number of males, I - immature, M - mature.

74 males were recorded. Fish measuring below 70 mm were immature. Males matured first between 71 to 80 mm, where 53.57% were mature and 46.43% were immature. Few immature males (10.00%) occurred between 81 and 90 mm, the rest 90.00% of them being mature. All males recorded above 91 mm were fully mature (Table 46). Sex-ratio for C. octofasciatus was 1:1.64, while the fecundity range was 1060 to 2879. All individuals were collected from Gulf of Mannar region (Keelakkarai group of islands).

Two distinct modes of ova were observed at 0.54 and 0.74 mm in the polygon. The large ova are also not separated from the small ova indicating that the species spawns continuously. The largest size of ova was 0.74 mm (Fig 47 E).

Ripe and spent fishes occurred in greater proportions in May, June, July '91 (33.33, 21.43 & 40.0% respectively), September and October (33.33% each) and February '92 (36.36%). Mature fish occurred consistently round the year except in August, November and December (Table 67, Fig 50 E).

6. Chaetodon trifasciatus: 125 individuals were examined. Indeterminate fishes (28 nos) occurred between 51 to 80 mm. 58 females were recorded and sex was identified between 71 to 80 mm where all individuals were immature. Size at first maturity for females was 81 to 90 mm where 60.00% were mature fish and 40.00% were immature. With a few immature fish (14.30%) in the size range of 91 to 100 mm, the proportion of mature fish was 85.70%. All individuals measuring above 101 mm were fully mature.

39 males were recorded. Fish recorded in the size range of 71 to 80 mm were immature. Size at first maturity for males was between 81 to 90 mm. Males measuring above 81 mm were mature (Table 47). Sex ratio for C. trifasciatus was 1:0.67 while the fecundity range was 1984 - 21975.

Four groups of ova were recorded at 0.22, 0.42, 0.67 and 0.86 mm but they were not separated from each other. Continuous spawning activity is indicated in the species. The largest ova measured 0.93 mm (Fig 47 F).

Spawning fishes occurred in higher proportions during August, September, October, November, December '91 and January '92 (40.00 to 58.33%) and during March and April '92 (63.64 and 40.00%). Mauture fish were not observed in February, June and July, while they were observed from August to January and during March, April and May (Table 67, Fig 50 F).

7. Cheilio inermis: 92 individuals were examined. Indeterminate fishes (26 nos) were recorded between 61 to 120 mm where sex of few individuals was identifiable. Samples measuring below 61 mm could not be procured. 61 females were recorded. Size at first maturity for females was between 121 and 150 mm, where all individuals were mature. Fishes occurring above this size range were mature.

Only 5 males were recorded in the size groups, 271 to 300 mm and 301 to 330 mm and were fully mature (Table 48). Sex - ratio for C. inermis was 1:0.8 while the fecundity range was 2982 to 6834.

Tables 46 & 47. Size at first maturity for females and males of C. octofasciatus and C. trifasciatus (values in percent against size).

Table 46 Chaetodon octofasciatus				Females	Males		
Size (mm)	IND	NF	I	M	NM	I	M
41 - 50	16	-	-	-	-	-	-
51 - 60	14	-	-	-	-	-	-
61 - 70	12	8	100.00	-	20	100.00	-
71 - 80	33	15	40.00	60.00	28	46.43	53.57
81 - 90	-	12	-	100.00	10	10.00	90.00
91 - 100	-	10	-	100.00	16	-	100.00
	75	45			74		

Table 47 Chaetodon trifasciatus				Females	Males		
Size (mm)	IND	NF	I	M	NM	I	M
51 - 60	5	-	-	-	-	-	-
61 - 70	7	-	-	-	-	-	-
71 - 80	16	8	100.00		8	100.00	-
81 - 90	-	15	40.00	60.00	5	-	100.00
91 - 100	-	14	14.30	85.70	10	-	100.00
101 - 110	-	11	-	100.00	2	-	100.00
111 - 112	-	10	-	100.00	14	-	100.00
	28	58			39		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

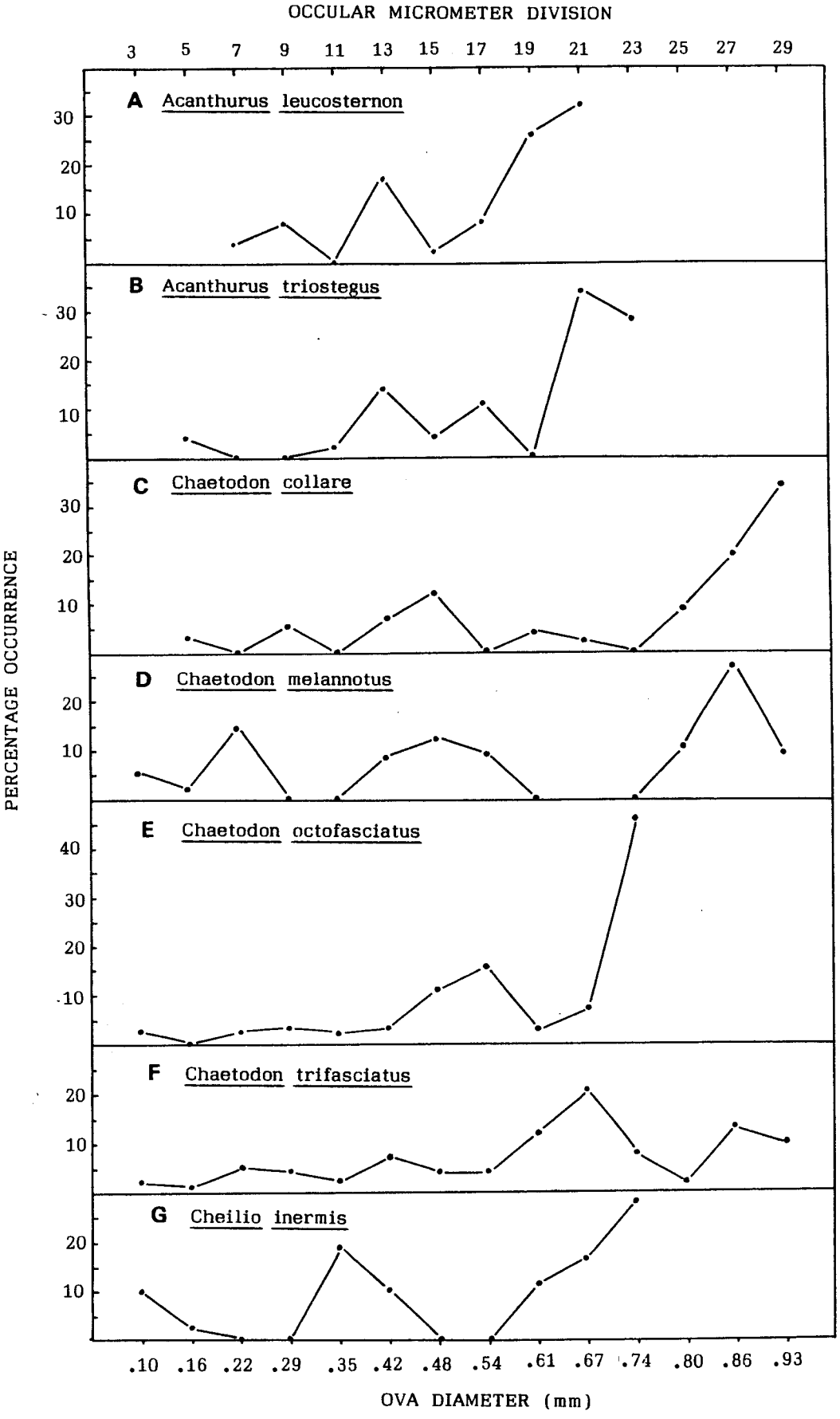

Figure 47. Ova diameter frequency polygons of 7 coral reef fishes. (A to G)

Apart from the small ova, two groups of large ova with modes at 0.35 and 0.74 mm were noticed. As the two groups of mature ova are separated from one another, the species is likely to spawn at intervals. Maximum size of ova was 0.74 mm (Fig 47 G).

Spawning fishes occurred in high proportions during November, December '91, January, February, March and April '92 (60.00 to 100.00%). Few mature individuals were observed in September and November accounting for percentage of 33.33% each. Spawning fishes were observed from November to April (Table 67, Fig 50 G).

8. Chrysiptera unimaculata: 169 individuals were examined. Indeterminate fishes (39 nos) occurred in the size group, 11 to 20 mm. 84 females were recorded and sex was identifiable between 21 and 30 mm where all fish were immature. Size at first maturity for females was between 31 and 40 mm with proportions of mature and immature females being 66.70 and 33.30% respectively. Few immature females (2.63%) occurred between 41 and 50 mm. All fish measuring above 51 mm were mature.

46 males were recorded. Sex was identifiable between 21 and 30 mm where all fish were immature. Size at first maturity for males was between 31 and 40 mm the proportions of mature and immature fishes being 14.30 and 85.70% respectively. Few immature males (12.50%) were also recorded between 41 and 50 mm while the rest (87.50%) were mature. Fishes measuring above 51 mm were mature (Table 49). Sex-ratio for C. unimaculata was 1:0.55 while the fecundity range was 1265 to 4592.

Tables 48 & 49. Size at first maturity for females and males of Cheilio inermis and Chrysiptera unimaculata (values in percent against size).

Table 48 Cheilio inermis			Females		Males		
Size (mm)	IND	NF	I	M	NM	I	M
61 - 90	10	5	100.00	-	-	-	-
91 - 120	16	4	10.00	-	-	-	-
121 - 150	-	9	-	100.00	-	-	-
151 - 180	-	15	-	100.00	-	-	-
181 - 210	-	-	-	-	-	-	-
211 - 240	-	13	-	100.00	-	-	-
241 - 270	-	8	-	100.00	-	-	-
271 - 300	-	2	-	100.00	4	-	100.00
301 - 330	-	5	-	100.00	1	-	100.00
	26	61			5		

Table 49 Chrysiptera unimaculata			Females		Males		
Size (mm)	IND	NF	I	M	NM	I	M
11 - 20	39	-	-	-	-	-	-
21 - 30	-	22	100.00	-	5	100.00	-
31 - 40	-	9	33.30	66.70	7	85.70	14.30
41 - 50	-	38	2.63	97.37	16	12.50	87.50
51 - 60	-	10	-	100.00	12	-	100.00
61 - 70	-	5	-	100.00	6	-	100.00
	39	84			46		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

Five groups of ova may be seen in the polygon with modes at 0.16, 0.42, 0.61, 0.74 and 0.86 mm distinctly separated Spawning activity in the species is inferred to be continuous. Maximum size of the ova was 0.86 mm (Fig 48 A).

Higher proportions of spawning fishes were observed in March (66.67%), May (50.00%), October '91 (100.00%) and April '92 (80.00%). Relatively more mature fishes were recorded in March '91 (66.67%), though they occurred in all months except in August and September (Table 67, Fig 50 H).

9. Dascyllus trimaculatus: 208 individuals were examined. Indeterminate fishes (47 nos) occurred upto 30 mm. 108 females were recorded. Size at first maturity for females was between 31 to 40 mm where the proportions of mature and immature fish were 89.66 and 10.34% respectively. A similar trend in the size range, 41 to 50 mm was observed with proportions of 82.14 and 17.86% respectively. All fishes recorded above 51 mm were mature.

53 males were recorded. All fishes occuring between 31 to 50 mm were immaure. Size at first maturity for males was between 51 to 60 mm, the proportions of mature and immature fish being 75.00 and 25.00% respectively. All fish measuring above 61 mm were mature (Table 50). Sex-ratio for D. trimaculatus was 1:0.49 while the fecundity range was 809 to 9634.

Four modes were evident from the polygon at 0.16, 0.35, 0.54 and 0.67 mm. As none of the modes were separated from each other, the species is likely to spawn continuously. The largest ova measured 0.74 mm (Fig 48 B).

Spawning fishes occurred in higher proportions during April and May '91 (66.67 and 77.78% respectively), August, September, October, November and December '91 (41.67 to 70.00%) and March and April '92 (75.00 and 70.00% respectively). Except in the monsoon months (June and July), D. trimaculatus occurred in all months (Table 67, Fig 50 I).

10. Gnathodentex aureolineatus: 157 individuals were examined. Indeterminate fishes (47 nos) occurred between 61 and 100 mm. 69 females were recorded. Sex was identifiable between 91 and 100 mm. Immature fish occurred in the size group, 91 to 110 mm. Size at first maturity was between 111 to 120 mm, proportions of mature and immature fish being 90.00 and 10.00% respectively. Few immature females (25.00%) were observed between 121 and 130 mm, the rest (75.00%) being mature females. Fishes measuring above 131 mm were mature.

41 males were recorded. Fishes measuring between 91 and 120 mm were immature. Size at first maturity for males was between 121 and 130 mm, proportions of mature and immature fish being 80.00 and 20.00% respectively. Few immature males (8.70%) were recorded

between 131 and 140 mm, the rest (91.30%) being mature fish. Fishes measuring above 141 mm were mature (Table 51). Sex-ratio for G. aureolineatus was 1:0.59 while the fecundity range was 19800 to 45632.

Although three groups of ova with modes at 0.16, 0.48 and 0.74 mm are present, they remained distinctly separated indicating breaks in spawning activity. Largest ova measured 0.80 mm (Fig 48 C).

Spawning fishes occurred in higher proportions during August, September and October '91 (64.29, 100.00 and 100.00% respectively). They were also recorded in February (75.00%) and April '91 (75.00%). In general two distinct seasons, January to April and August to November were evident in an year (Table 67, Fig 50 J).

11. Halichoeres scapularis: 207 individuals were examined. Indeterminate fishes (34 nos) occurred between 31 and 50 mm, 150 females were recorded. Size at first maturity was between 51 and 60 mm, proportions of mature and immature fish being 40.00 and 60.00% respectively. Immature fish continued to occur in two size groups of 61 to 70 mm and 71 to 80 mm with proportions of 25.00 and 26.92% respectively, the mature fish accounting for 75.00 and 73.08% respectively. Females measuing above 81 mm were mature. Females measuring greater than 141 mm were absent.

23 males were recorded. Immature fish occurred in the size group 51 and 60 mm. Size at first maturity for males was between 61 and 70 mm, proportions of mature and immature fishes being 71.40 and 28.60%

Tables 50 & 51. Size at first maturity for females and males of D. trimaculatus and G. aureolineatus (values in percent against size).

Table 50 Dascyllus trimaculatus				Females	Males		
Size (mm)	IND	NF	I	M	NM	I	M
1 - 10	5	-	-	-	-	-	-
11 - 20	40	-	-	-	-	-	-
21 - 30	2	-	-	-	-	-	-
31 - 40	-	29	10.34	89.66	2	100.00	-
41 - 50	-	28	17.86	82.14	14	100.00	-
51 - 60	-	3	-	100.00	12	25.00	75.00
61 - 70	-	12	-	100.00	8	-	100.00
71 - 80	-	20	-	100.00	11	-	100.00
81 - 90	-	5	-	100.00	3	-	100.00
91 - 100	-	11	-	100.00	3	-	100.00
	47	108			53		

Table 51 Ganthodentex aureolineatus				Females	Males		
Size (mm)	IND	NF	I	M	NM	I	M
61 - 70	9	-	-	-	-	-	-
71 - 80	12	-	-	-	-	-	-
81 - 90	22	-	-	-	-	-	-
91 - 100	4	5	100.00	-	2	100.00	-
101 - 110	-	6	100.00	-	-	-	-
111 - 120	-	10	10.00	90.00	8	100.00	-
121 - 130	-	12	25.00	75.00	5	20.00	80.00
131 - 141	-	26	-	100.00	23	8.70	91.30
141 - 150	-	10	-	100.00	3	-	100.00
	47	69			41		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

respectively. Mature males were observed to occur in the size ranges of 71 to 80 mm and larger males between 131 and 160 mm. Males measuring between 81 to 130 were not observed (Table 52). Sex-ratio for H. scapularis was 1:0.15, while the fecundity range was 9992 to 15633.

Three groups of ova with modes at 0.29, 0.48 and 0.67 mm were recorded but not distinctly separated from each other. The species is expected to spawn continuously. Maximum size of ova was 0.67 mm (Fig 48 D).

Spawning occurred during all months with highest proportions during April and May '91 (77.78 and 70.00%) and November and December '91 (88.46 and 80.00%). Except in March '91 that registered a low percentage of mature fish (12.50%) other months registered values between 33.33 and 73.33% (Table 67, Fig 51 A).

12. Lutjanus gibbus: 115 individuals were examined. Indeterminate fishes (35 nos) occurred between 61 and 100 mm. 48 females were recorded. Fishes measuring between 111 and 150 mm were immature. Size at first maturity for females was between 151 and 170 mm, proportions of mature and immature fish being 70.00 and 30.00% respectively. Few immature females (20.00%) were observed between 171 and 190 mm, the rest (80.00%) being mature fish. Fishes measuring above 191 mm were mature.

32 males were recorded. Immature males measured between 91 and 100 mm. Size at first maturity for males was between 111 and 130 mm, proportions of mature and immature fish being 25.00 and 75.00% respectively. Fishes measuing above 151 mm were mature (Table 53). Sex-ratio for Lutjanus gibbus was 1:0.67 while fecundity was between 46774 to 130698.

Apart from small ova, two groups of large ova with modes at 0.35 and 0.80 mm were present and were distinctly separated. Spawning activity may be at short intervals. Largest ova measured 0.80 mm (Fig 48 E).

Ripe and spent fishes occurred from January to April '91 with highest proportions during January (66.67%) and February (60.00%), August, September and October '91 (57.14, 55.56 and 41.67%) and from January to May '92 with a highest proportion in March (50.00%), while no fish were recorded in April '92. In general two distinct spawning seasons occurred from January to April and August to October (Table 67, Fig 51 B).

13. Lutjanus kasmira: 217 individuals were examined. Indeterminate fishes (49 nos) occurred between 31 and 90 mm. 96 females were recorded. Size at first maturity for females was in the size group 91 and 110 mm, proportions of mature and immature fish being 27.80 and 72.20% respectively. A majority of fishes measuring between 111 and 130 mm were mature (94.60%) while the rest were immature (5.40%). Fishes measuring above 131 mm were mature.

Tables 52 & 53. Size at first maturity for females and males of H. scapularis and L. gibbus (values in percent against size).

Table 52	Halichoeres scapularis			Females	Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 40	30	-	-	-	-	-	-
41 - 50	4	-	-	-	-	-	-
51 - 60	-	25	60.00	40.00	1	100.00	-
61 - 70	-	12	25.00	75.00	7	28.60	71.40
71 - 80	-	26	26.92	73.08	2	-	100.00
81 - 90	-	24	-	100.00	-	-	-
91 - 100	-	25	-	100.00	-	-	-
101 - 110	-	22	-	100.00	-	-	-
111 - 120	-	10	-	100.00	-	-	-
121 - 130	-	1	-	100.00	-	-	-
131 - 140	-	6	-	100.00	6	-	100.00
141 - 150	-	-	-	-	5	-	100.00
151 - 160	-	-	-	-	2	-	100.00
	34	150			23		

Table 53	Lutjanus gibbus			Females	Males		
Size (mm)	IND	NF	I	M	NM	I	M
61 - 80	21	-	-	-	-	-	-
81 - 90	3	-	-	-	-	-	-
91 - 100	11	-	-	-	4	100.00	-
111 - 130	-	6	100.00	-	8	75.20	25.00
131 - 150	-	2	100.00	-	-	-	-
151 - 170	-	10	30.00	70.00	3	-	100.00
171 - 190	-	5	20.00	80.00	4	-	100.00
191 - 210	-	10	-	100.00	3	-	100.00
211 - 230	-	7	-	100.00	8	-	100.00
231 - 250	-	3	-	100.00	1	-	100.00
251 - 270	-	1	-	100.00	-	-	-
271 - 290	-	-	-	-	-	-	-
291 - 310	-	4	-	100.00	1	-	100.00
	35	48			32		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

72 males were recorded. Fishes measuing between 71 and 110 mm were immature. Size at first maturity for males was between 111 and 130 mm, proportions of mature and immature males being 71.40 and 28.60%. Fishes measuring above 131 mm were mature (Table 54). Sex-ratio for L. kasmira was 1:0.75 while the fecundity range was 33752 to 225850.

Three groups of ova may be seen in the polygon with modes at 0.16, 0.35 and 0.74 mm which are separated from one another. The species is likely to spawn intermittently. The maximum size of ova measured 0.80 mm (Fig 48 F).

Spawning individuals were recorded during January and March '91 (66.67 and 68.75%) and October and December '91 (65.22 and 60.00%). A relatively higher proportion of mature fish were observed in June (80.00%) and November '91 (53.85%). A distinct spawning season from October to March was evident (Table 67, Fig 51 C).

14. Melichthys indicus: 108 individuals were examined. Indeterminate fishes (25 nos) occurred between 91 and 110 mm. 46 females were recorded. Sex was identified in the size group of 91 to 100 mm where all fishes were immature. Size at first maturity for females was between 111 and 120 mm, proportions of mature and immature fish being 62.50 and 37.50% respectively. Fishes measuring above 121 mm were mature.

37 males were recorded. Immature fish were observed in the size groups, 91 to 100 and 101 to 110 mm. Size at first maturity for males was between 111 and 120 mm, proportions of mature and immature fishes being 80.00 and 20.00% respectively. Fishes measuring above 121 mm were mature (Table 55). Sex-ratio for M. indicus was 1:0.80 while the fecundity range was 2056 to 9329.

The polygon indicates the presence of four modes at 0.16, 0.29, 0.61 and 0.86 mm. The species appears to spawn continuously but in spurts. The largest ova measured 0.86 mm (Fig 48 G).

Spawning individuals were recorded during April and May '91 (66.67% each), September, October and November '91 (56.25, 100.00 and 50.00% respectively), February '92 (61.54%) and April and May '92 (55.56 and 100.00%). All individuals observed in October '91 and May '92 were spawning fishes (100.00% each). Two spawning seasons from September to December and April/May were recorded (Table 67, Fig 51 D).

15. Mulloides flavolineatus: 170 individuals were examined. Indeterminate fishes (33 nos) occurred between 51 and 90 mm. 77 females were recorded. Size at first maturity for females was between 91 and 110 mm, proportions of mature and immature fishes being 57.69 and 42.30% respectively. Few immature fishes (14.29%) and mature fishes (85.71% occurred in the size range of 111 to 130 mm. Fishes measuring above 131 mm were mature.

Tables 54 & 55. Size at first maturity for females and males of L. kasmira and M. indicus (values in percent against size).

Table 54 Lutjanus kasmira		Females			Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 50	15	-	-	-	-	-	-
51 - 70	11	-	-	-	-	-	-
71 - 90	23	-	-	-	18	100.00	-
91 - 110	-	18	72.20	27.80	10	100.00	-
111 - 130	-	37	5.40	94.60	7	28.60	71.40
131 - 150	-	38	-	100.00	29	-	100.00
151 - 170	-	2	-	-	2	-	100.00
171 - 190	-	-	-	-	2	-	100.00
191 - 210	-	1	-	100.00	-	-	-
211 - 230	-	-	-	-	4	-	100.00
	49	96			72		

Table 55 Melichthys indicus		Females			Males		
Size (mm)	IND	NF	I	M	NM	I	M
91 - 100	17	6	100.00	-	6	100.00	-
101 - 110	8	-	-	-	10	100.00	-
111 - 120	-	8	37.50	62.50	10	20.00	80.00
121 - 130	-	4	-	100.00	4	-	100.00
131 - 140	-	5	-	100.00	1	-	100.00
141 - 150	-	11	-	100.00	5	-	100.00
151 - 160	-	5	-	100.00	-	-	-
161 - 170	-	6	-	100.00	1	-	100.00
171 - 180	-	1	-	100.00	-	-	-
	25	46			37		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

60 males were recorded. Size at first maturity was between 91 and 110 mm with equal proportions of immature and mature fishes (50.00% each). Fishes measuring above 111 mm were mature (Table 56). Sex ratio for M. flavolineatus was 1:0.78 while the fecundity range was 4638 to 12946.

Two groups of ova are indicated in the polygon with modes at 0.42 and 0.67 mm but not separated. The species is likely to spawn continuously. The maximum size of ova measured 0.74 mm (Fig 48 H).

Spawning fishes occurred in high proportions during March (80.00%), April (70.37%) and May '91 (66.67%). Proportions during the same months in '92 were relatively low. Spawning individuals were also found in October and November '91 (52.94 & 33.33%). In general two seasons from January to May and October/November were observed (Table 67, Fig 51 E).

16. Myripristis murdjan: 188 individuals were examined. Indeterminate fishes (56 nos) occurred between 31 and 80 mm. 89 females were recorded. Sex was identifiable between 71 and 80 mm, all individuals being immature. All fishes recorded in the size group 91 to 100 mm were also immature. Individuals belonging to size groups 61 to 70, 81 to 90 and 101 to 110 mm were not available. Size at first maturity for females was between 111 and 120 mm, proportions of mature and immature fishes being 69.20 and 30.80% respectively. Few immature females (19.57%) were observed in the size group 121 to 130 mm while the rest (80.43) were mature fish. All fishes measuring above 131 mm were mature.

43 males were recorded. Size at first maturity for males was between 71 and 80 mm, proportions of mature and immature fishes being 40.00 and 60.00% respectively. Fishes measuring above 81 mm were mature (Table 57). Sex-ratio for M. murdjan was 1:0.48 while the fecundity range was 11163 to 22689.

The ova diameter frequency polygon indicated four groups of ova with modes at 0.22, 0.42, 0.61 and 0.86 mm. The modes were not separated from each other, indicating a continuous spawning habit. The largest ova measured 0.86 mm (Fig 48 I).

Spawning fishes occurred in higher proportions in April (55.56%) and December '91 (69.23%). In general spawning individuals were observed from November to May (10.00 to 69.23%) with a gap in February. A single spawning fish was recorded in September '91 (Table 67, Fig 51 F).

17. Neoniphon sammara: 178 individuals were examined. Indeterminate fishes (54 nos) occurred between 31 and 60 mm. 89 females were recorded. Sex was identifiable in the size group, 61 to 70 mm where all fish were immature. Size at first maturity for females was between 71 and 80 mm, proportions of mature and immature fishes being 92.86 and 7.14% respectively. Few immature females (11.10%) were observed in the size group 81 to 90 mm, the rest (88.90%) being mature fish. Females measuring above 91 mm were mature.

Tables 56 & 57. Size at first maturity for females and males of Mulloides flavolineatus and Myripristis murdjan (values in percent against size).

Table 56 Mulloides flavolineatus		Females			Males		
Size (mm)	IND	NF	I	M	NM	I	M
51 - 70	21	-	-	-	-	-	-
71 - 90	12	-	-	-	-	-	-
91 - 110	-	26	42.31	57.69	3	50.00	50.00
111 - 130	-	14	14.29	85.71	5	-	100.00
13 - 150	-	14	-	100.00	10	-	100.00
151 - 170	-	9	-	100.00	21	-	100.00
171 - 190	-	4	-	100.00	15	-	100.00
191 - 210	-	10	-	100.00	6	-	100.00
	33	77			60		

Table 57 Myripristis murdjan		Females			Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 40	26	-	-	-	-	-	-
41 - 50	20	-	-	-	-	-	-
51 - 60	6	-	-	-	-	-	-
61 - 70	-	-	-	-	-	-	-
71 - 80	4	8	100.00	-	15	60.00	40.00
81 - 90	-	-	-	-	11	-	100.00
91 - 100	-	3	100.00	-	2	-	100.00
101 - 110	-	-	-	-	-	-	-
111 - 120	-	13	30.80	69.20	-	-	-
121 - 130	-	46	19.57	80.43	4	-	100.00
131 - 140	-	8	-	100.00	1	-	100.00
141 - 150	-	10	-	100.00	10	-	100.00
151 - 160	-	-	-	-	-	-	-
161 - 170	-	1	-	100.00	-	-	-
	56	89			43		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

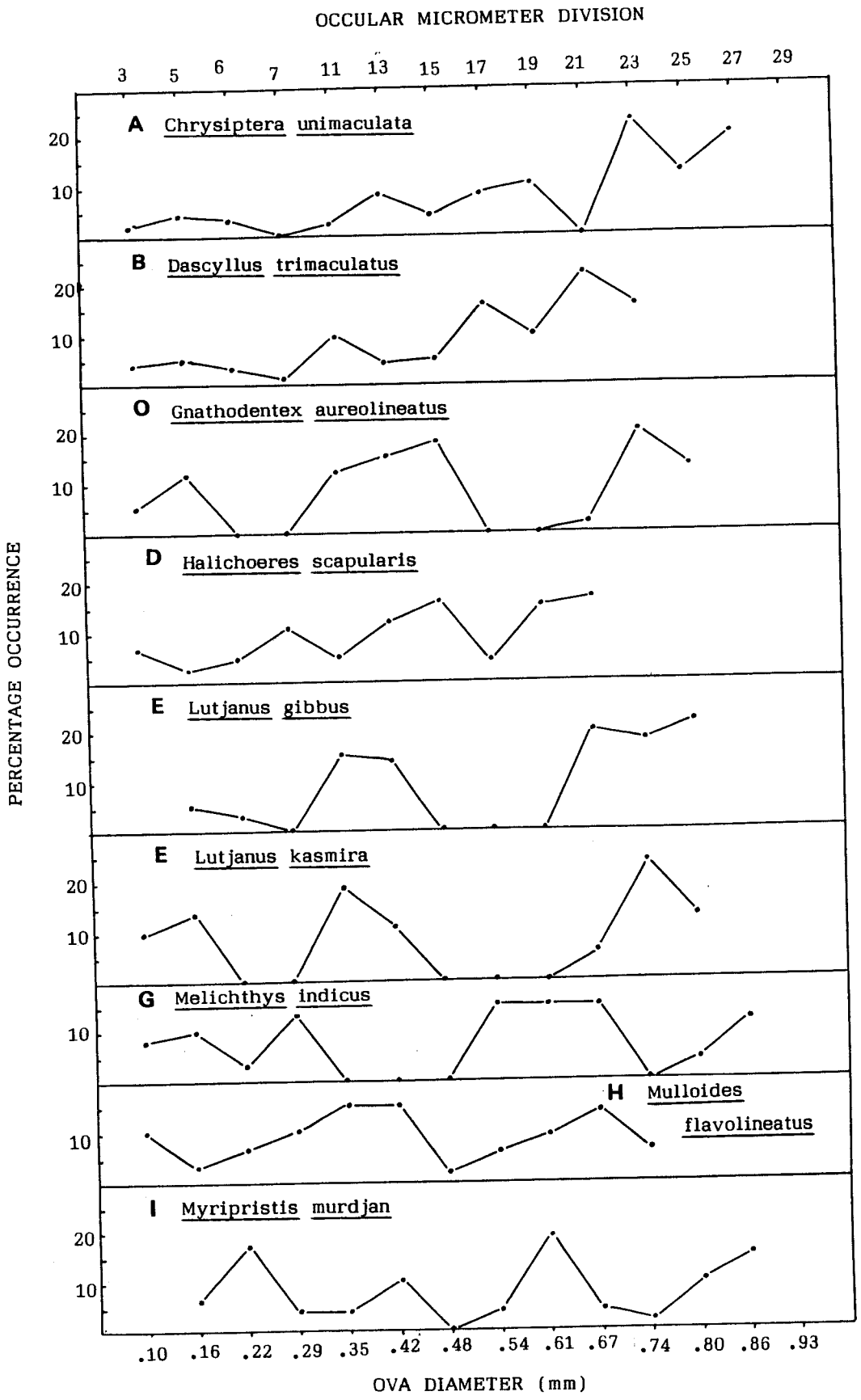

Figure 48. Ova diameter frequency polygons of 9 coral reef fishes. (A to I)

35 males were recorded. All fish examined in the size range 61 to 70 mm were immature. Size at first maturity for males was between 71 and 80 mm, the proportions of mature and immature fish being 66.70 and 33.60%. Few immature females (20.00%) were observed in the size group, 81 to 90 mm, the rest (80.00%) being mature fish. Fully mature fish occurred in sizes measuring above 111 mm (Table 58). The sex-ratio for N. sammara was 1:0.39 while the fecundity range was 7973 to 15323.

The frequency polygon indicated three groups of ova with modes at 0.22, 0.35 and 0.61 mm. The species is likely to spawn continuously. The maximum size of ova measured 0.67 mm (Fig 49 A).

Spawning fishes occurred in higher proportions in December '91, February and April '92 (66.67, 68.00 and 81.82% respectively). In general spawning fishes were observed from November to May (proportions between 58.33 and 81.82%) with a gap in January. Spawning individuals were not observed from June to October (Table 67, Fig 51 G).

18. Paracirrhites forsteri: 89 individuals were examined. Indeterminate fishes (18 nos) occurred between 31 and 60 mm. 49 females were recorded. Sex was identifiable in the size group, 51 - 60 mm where all fish were immature. Fishes in the size group 61 to 70 mm were not available. Size at first maturity for females was between 71 and 80 mm, proportions of mature and immature fishes being 28.60 and

71.40% respectively. Few immature females (4.76%) occurred in the size group, 81 to 90 mm, the rest (95.24%) being mature fish. Fish measuring above 91 mm were mature.

22 males were recorded. Size at first maturity was between 51 and 60 mm, proportions of mature and immature fish being equal (50.00% each). Males measuring above 61 mm were mature (Table 59). Sex-ratio for P. forsteri was 1:0.45 while the fecundity range was 734 to 1894.

Two groups of ova with modes at 0.22 and 0.54 mm are indicated in the polygon. The species may spawn continuously with short intervals. The largest size of ova was 0.61 mm (Fig 49 B).

Spawning fishes were observed in high proportions in October and November '91 (100.00 and 55.56%). Spawning individuals continuously occurred from January to May '91 with proportions varying between 25.00 and 50.00%. Spawning individuals were not observed from June to September '91 (Table 67, Fig 51 H).

19. Parupeneus barberinus: 173 individuals were examined. Indeterminate fishes (49 nos) occurred between 31 and 100 mm. 77 females were recorded. Size at first maturity for females was between 111 and 130 mm, proportions of mature and immature fishes being 27.80 and 72.20% respectively. Few immature females (16.70%) were observed in the size group 131 to 150, the rest (83.30%) being mature fish. Fishes measuring above 151 mm were mature.

Tables 58 & 59. size at first maturity for females and males of N. sammara and P. forsteri (values in percent against size).

Table 58 Neoniphon sammara		Females			Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 40	17	-	-	-	-	-	-
41 - 50	26	-	-	-	-	-	-
51 - 60	11	-	-	-	-	-	-
61 - 70	-	7	100.00	-	8	100.00	-
71 - 80	-	14	7.14	92.86	3	33.60	66.70
81 - 90	-	18	11.10	88.90	5	20.00	80.00
91 - 100	-	12	-	100.00	-	-	-
101 - 110	-	12	-	100.00	-	-	-
111 - 120	-	3	-	100.00	2	-	100.00
121 - 130	-	9	-	100.00	1	-	100.00
131 - 140	-	6	-	100.00	12	-	100.00
141 - 150	-	8	-	100.00	4	-	100.00
	54	89			35		

Table 59 Paracirrhites forsteri		Females			Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 40	7	-	-	-	-	-	-
41 - 50	5	-	-	-	-	-	-
51 - 60	6	2	100.00	-	2	50.00	50.00
61 - 70	-	-	-	-	4	-	100.00
71 - 80	-	14	71.40	28.60	9	-	100.00
81 - 90	-	21	4.76	95.24	-	-	-
91 - 100	-	11	-	100.00	7	-	100.00
101 - 110	-	1	-	100.00	-	-	-
	18	49			22		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

47 males were recorded. Immature fish were observed between 111 to 150 mm. Size at first maturity for males was between 151 to 170 mm, proportions of mature and immature fish being 21.40 and 78.60% respectively. Fishes measuring above 171 mm were mature (Table 60). Sex-ratio for P. barberinus was 1:0.61 while the fecundity range was 9234 to 10988.

The ova diameter frequency polygon indicated three modes at 0.16, 0.42 and 0.67 mm which are not distinctly separated. The species is expected to spawn continuously. The maximum size of the ova measured 0.74 mm (Fig 49 C).

Spawning individuals occurred in high proportions in January (61.54%) March '91 (57.89%), January '92 (58.82%), April (60.00%) and May (50.00%), In general, spawning individuals were observed from October to May except in December and February when they were not recorded. Spawning fishes were also not observed in July, August and September (Table 67, Fig 51 I).

20. Parupeneus bifasciatus: 119 individuals were examined. Indeterminate fish (31 nos) occurred between 31 and 90 mm. 55 females were recorded. Size at first maturity for females was between 91 and 110 mm, proportions of mature and immature fish being 55.60 and 44.40% respectively. Few immature fishes (12.50%) were observed between 111 and 130 mm, the rest (87.50%) being mature fish. Females measuring above 131 mm were mature.

33 males were recorded. Immature fish were observed between 91 and 130 mm. Size at first maturity for males was between 131 and 150 mm, proportions of mature and immature fish being 77.80 and 22.20% respectively. Males measuring above 151 mm were mature (Table 61). Sex-ratio for P. bifasciatus was 1:0.60 while the fecundity range was 2968 to 146373.

The three groups of ova present are not separated from one another with modes at 0.22, 0.48 and 0.67 mm, the species is likely to spawn continuously. The maximum size of ova measured 0.80 mm (Fig 49 D).

Ripe and spent individuals were observed in high proportions in March (77.78%), October '91 (53.64%) January (71.43%) and February '92 (61.54%). Spawning individuals were recorded from September to April and were not observed in June, July, August and December (Table 67, Fig. 51 J).

21. Plectorhinchus orientalis: 109 individuals were examined. Indeterminate fishes (21 nos) occurred between 31 and 130 mm. 56 females were recorded. Immature fishes occurred between 131 and 180 mm. Size at first maturity for females was between 181 and 230 mm, proportions of mature and immature fish being 58.80 and 41.20% respectively. Fishes measuring above 231 mm were mature.

32 males were recorded. Immature fish were observed between 181 and 230 mm. Size at first maturity for males was between 231 and 280

Tables 60 & 61. Size at first maturity for females and males of P. barberinus and P. bifasciatus (values in percent against size).

Table 60 Parupeneus barberinus	Females,			Males			
Size (mm)	IND	NF	I	M	NM	I	M
31 - 50	8	-	-	-	-	-	-
51 - 70	5	-	-	-	-	-	-
71 - 90	14	-	-	-	-	-	-
91 - 100	22	-	-	-	-	-	-
111 - 130	-	18	72.20	27.80	6	100.00	-
131 - 150	-	12	16.70	83.30	12	100.00	-
151 - 170	-	28	-	100.00	14	78.60	21.40
171 - 190	-	2	-	100.00	12	-	100.00
191 - 210	-	12	-	100.00	3	-	100.00
211 - 230	-	2	-	100.00	-	-	-
231 - 250	-	3	-	100.00	-	-	-
	49	77			47		

Table 61 Parupeneus bifasciatus	Females,			Males			
Size (mm)	IND	NF	I	M	NM	I	M
31 - 50	12	-	-	-	-	-	-
51 - 70	14	-	-	-	-	-	-
71 - 90	5	-	-	-	-	-	-
91 - 110	-	9	44.40	55.60	3	100.00	-
111 - 130	-	16	12.50	87.50	4	100.00	-
131 - 150	-	6	-	100.00	9	22.20	77.80
151 - 170	-	15	-	100.00	16	-	100.00
171 - 190	-	9	-	100.00	1	-	100.00
	31	55			33		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

mm, proportions of mature and immature fish being 84.20% and 15.80% respectively. Males measuring above 281 mm were mature (Table 62). Sex-ratio for P. orientalis was 1:0.57 while the fecundity range was 8927 to 16342.

Only two groups of ova with modes at 0.35 and 0.74 mm are present. Since the two modes are separate, the species may spawn at intervals. Largest ova measured 0.80 mm (Fig 49 E).

Spawning individuals occurred in high proportions in the month of April '91 & '92 accounting for 64.29 and 66.27% respectively. In general, spawning individuals were recorded from December to May while they were not observed in February, June, July and August (Table 67, Fig 52 A).

22. Pomacentrus pavo: 352 individuals were examined. Indeterminate fishes (46 nos) occurred between 21 and 30 mm. 194 females were recorded. Sex was identifiable in the size group, 31 to 40 mm where all fishes were immature. Size at first maturity for females was between 41 and 50 mm, proportions of mature and immature fishes being 92.86 and 7.14% respectively. Immature females (10.53%) were also observed between 51 and 60 mm, rest of the individuals being mature fish (89.47%). Females measuring above 61 mm were mature.

112 males were recorded. Immature fish were observed in the size group, 31 to 40 mm. Size at first maturity for males was between 41 and 50 mm, proportions of mature and immature fish being 75.76 and

24.24% respectively. Immature males (39.13%) were also found in the size group, 51 to 60 mm, rest of the individuals being mature fish (60.87%). Males measuring above 61 mm were mature (Table 63). Sex-ratio for P. pavo was 1:0.58 while the fecundity range was 700 to 2396.

The ova diameter frequency polygon indicates three groups of ova with modes at 0.22, 0.45 and 0.80 mm which are not separated from each other. The species is likely to spawn continuously. The largest ova measured 0.86 mm (Fig 49 F).

Spawning fishes occurred in high proportions in March '91 (80.77%), April (75.00%) and May '92 (78.79%). Spawning individuals were observed continuously from January to December in relatively high proportions ranging between 16.67 to 80.77% (Table 67, Fig 52 B).

23. Rhinecanthus aculeatus: 166 individuals were examined. Indeterminate fishes (43 nos) occurred between 21 and 70 mm. 71 females were recorded. Immature fish were observed in the size ranges of 71 to 80 and 81 to 90 mm. Size at first maturity for females was between 91 and 100 mm, proportions of mature and immature fishes being 25.00 and 75.00% respectively. Few immature fishes (53.33%) were observed between 101 and 110 mm, the rest (46.67%) being mature females. Females recorded above 111 mm were mature.

52 males were recorded. Immature fish were observed in the size group, 71 to 80 mm. Size at first maturity for males was between 81 and 90 mm, proportions of mature and immature fishes being 11.10 and

Tables 62 & 63. Size at first maturity for females and males of Plectorhinchus orientalis and Pomacentrus pavo (values in percent against size).

Table 62 Plectorhinchus orientalis	Females,				Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 80	13	-	-	-	-	-	-
81 - 130	8	-	-	-	-	-	-
131 - 180	-	21	100.00	-	-	-	-
181 - 230	-	17	41.20	58.80	4	100.00	-
231 - 280	-	3	-	100.00	19	15.80	84.20
281 - 330	-	13	-	100.00	9	-	100.00
331 - 380	-	2	-	100.00	-	-	-
	21	56			32		

Table 63 Pomacentrus pavo	Females,				Males		
Size (mm)	IND	NF	I	M	NM	I	M
21 - 30	46	-	-	-	-	-	-
31 - 40	-	25	100.00	-	16	100.00	-
41 - 50	-	42	7.14	92.86	33	24.24	75.76
51 - 60	-	76	10.53	89.47	23	39.13	60.87
61 - 70	-	33	-	100.00	14	-	100.00
71 - 80	-	10	-	100.00	16	-	100.00
81 - 90	-	8	-	100.00	10	-	100.00
	46	194			112		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

88.90% respectively. Mature and immature males continued to occur in the size ranges of 81 to 90, 111 to 120 and 121 to 130 mm with proportions of 33.30 and 66.70, 80.00 and 20.00 and 64.71 and 35.29% respectively. Males measuring above 131 mm were mature (Table 64). Sex-ratio for R. aculeatus was 1:0.73 while the fecundity range was 936 to 7262.

The polygon represents three groups of ova with modes at 0.35, 0.54 and 0.67 mm. Since the groups are not separated from one another, the species is expected to spawn continuously. The largest group of ova measured 0.74 mm (Fig 49 G).

Spawning individuals occurred in high proportions in the month of April '91 & 92 accounting for 60.00 and 61.54% respectively. In general, spawning individuals were observed continuously except during February, June and July (Table 67, Fig 52 C).

24. Thalassoma hardwicki: 148 individuals were examined. Indeterminate fishes (32 nos) occurred between 31 and 50 mm. 94 females were recorded. Immature females were observed in the size group of 51 to 60 and 61 to 70 mm. Size at first maturity for females was between 81 and 90 mm, proportions of mature and immature fish being 33.30 and 66.70% respectively. Females measuring above 91 mm were mature.

22 males were recorded. Immature fish were found in the size groups of 51 to 60 and 61 to 70 mm. Males measuring between 71 and

100 mm were not available. Fishes measuring above 101 mm were mature (Table 65). Sex-ratio of T. hardwicki was 1:0.23 while the fecundity range was 4600 to 8743.

Only two groups of ova are represented in the polygon with modes at 0.22 and 0.67 mm. Since the modes are separated, the species may spawn intermittently. Maximum size of ova was 0.74 mm (Fig 49 H).

Spawning individuals occurred in high proportions in April '91 (81.82%) May (75.00%), November (100.00%) and December (77.78%). In general, spawning fishes were observed from February to May and September to December, while they were not recorded in January, June July and August (Table 67, Fig 52 D).

25. Thalassoma lunare: 99 individuals were examined. Indeterminate fishes (25 nos) occurred between 41 and 70 mm. 58 females were recorded. Immature fish were observed in two size groups, 71 to 80 and 81 to 90 mm. Size at first maturity for females was between 91 and 100 mm, proportions of mature and immature fishes being 62.50 and 37.50% respectively. Few immature females (23.10%) were observed between 101 and 110 mm, the rest (76.90%) being mature fish. Females measuring above 111 mm were mature.

16 males were recorded. Immature fish were observed in the size group 81 to 90 mm. Males in the sizes betwen 91 to 130 mm were not available. Fishes measuring above 131 mm were mature (Table 66). Sex-ratio for T. lunare was 1:0.28 while the fecundity range was 3342 to 10360.

Tables 64 & 65. Size at first maturity for females and males of R. aculeatus and T. hardwicki (values in percent against size).

Table 64 Rhinecanthus aculeatus		Females			Males.		
Size (mm)	IND	NF	I	M	NM	I	M
21 - 30	7	-	-	-	-	-	-
31 - 40	13	-	-	-	-	-	-
41 - 50	12	-	-	-	-	-	-
51 - 60	4	-	-	-	-	-	-
61 - 70	7	-	-	-	-	-	-
71 - 80	-	10	100.00	-	3	100.00	-
81 - 90	-	2	100.00	-	9	88.90	11.10
91 - 100	-	12	75.00	25.00	9	66.70	33.30
101 - 110	-	15	53.33	46.67	-	-	-
111 - 120	-	9	-	100.00	5	20.00	80.00
121 - 130	-	12	-	100.00	17	35.29	64.71
131 - 140	-	3	-	100.00	5	-	100.00
141 - 150	-	1	-	100.00	4	-	100.00
151 - 160	-	-	-	-	-	-	-
161 - 170	-	7	-	100.00	-	-	-
	43	71			52		

Table 65 Thalassoma hardwicki		Females			Males		
Size (mm)	IND	NF	I	M	NM	I	M
31 - 40	21	-	-	-	-	-	-
41 - 50	11	-	-	-	-	-	-
51 - 60	-	7	100.00	-	1	100.00	-
61 - 70	-	7	100.00	-	3	100.00	-
71 - 80	-	-	-	-	-	-	-
81 - 90	-	12	66.70	33.30	-	-	-
91 - 100	-	16	-	100.00	-	-	-
101 - 110	-	10	-	100.00	2	-	100.00
111 - 120	-	14	-	100.00	2	-	100.00
121 - 130	-	20	-	100.00	-	-	-
131 - 140	-	8	-	100.00	14	-	100.00
	32	94			22		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

Table 66. Size at first maturity for females and males T. lunare (values in percent against size).

Table 66 Thalassoma lunare			Females		Males		
Size (mm)	IND	NF	I	M	NM	I	M
41 - 50	12	-	-	-	-	-	-
51 - 60	12	-	-	-	-	-	-
61 - 70	1	-	-	-	-	-	-
71 - 80	-	5	100.00	-	-	-	-
81 - 90	-	4	100.00	-	9	100.00	-
91 - 100	-	8	37.50	62.50	-	-	-
101 - 110	-	13	23.10	76.90	-	-	-
111 - 120	-	14	-	100.00	-	-	-
121 - 130	-	6	-	100.00	-	-	-
131 - 140	-	-	-	-	1	-	100.00
141 - 150	-	5	-	100.00	5	-	100.00
151 - 160	-	2	-	100.00	1	-	100.00
161 - 170	-	-	-	-	-	-	-
171 - 180	-	-	-	-	-	-	-
181 - 190	-	1	-	100.00	-	-	-
	25	58			16		

IND - Indeterminate, NF - number of females, NM - number of males, I - immature, M - mature.

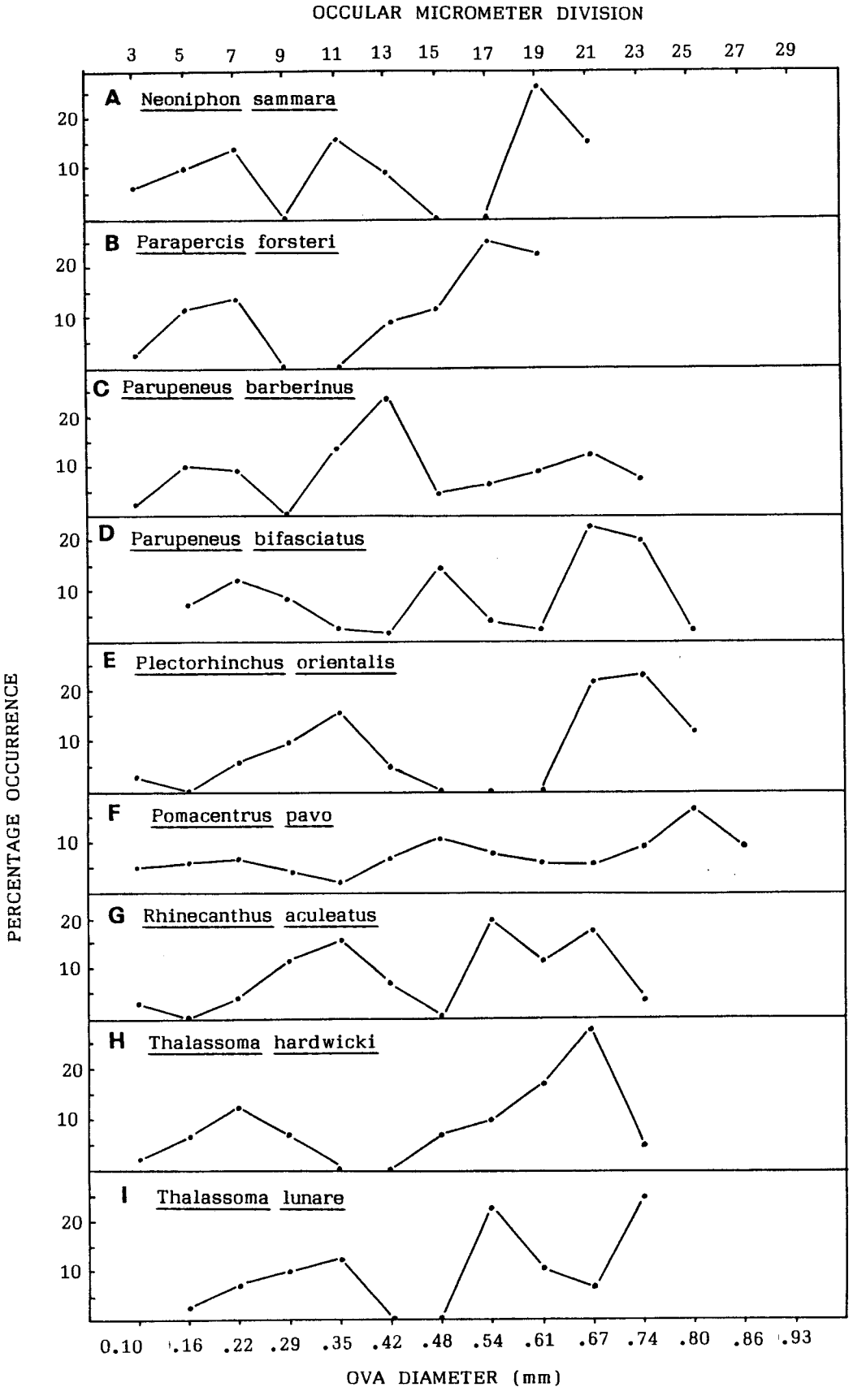

Figure 49. Ova diameter frequency polygons of 9 coral reef fishes. (A to I)

Table 67. Percentage occurrence of ripe individuals of 25 coral reef fishes from January 1991 to June 1992. (A - Total number of fishes obtained, B - number of ripe fish, C - percentage of ripe fish).

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
	Acanthurus leucosternon																	
A.	18	5	16	8	4	4	2	8	14	5	9	10	15	16	4	6	3	1
B.	9	4	2	6	-	3	-	-	2	2	3	4	8	-	3	5	-	-
C.	50.00	80.00	12.50	75.00	-	75.00	-	-	14.29	40.00	33.33	40.00	53.33	-	75.00	83.33	-	-
	A. triostegus																	
A.	17	12	8	9	10	2	2	15	16	12	13	16	11	19	10	27	8	9
B.	4	5	5	5	6	-	-	1	5	-	9	8	2	7	7	5	4	-
C.	23.33	41.67	62.50	55.56	60.00	-	-	6.67	31.25	-	69.23	50.00	18.18	36.84	70.00	18.52	50.00	-
	Chaetodon collare																	
A.	12	10	4	10	9	10	9	14	10	13	11	9	8	14	16	13	5	8
B.	-	1	2	4	2	-	-	1	2	-	-	2	2	4	9	2	1	1
C.	-	10.00	14.29	40.00	22.22	-	-	7.14	20.00	-	-	22.22	25.00	28.57	56.25	15.38	20.00	12.50
	C. melannotus																	
A.	10	3	13	15	5	4	10	20	13	20	12	14	3	16	8	12	8	2
B.	1	2	6	4	-	-	-	1	4	1	3	-	2	2	5	7	3	-
C.	10.00	66.67	46.15	26.67	-	-	-	5.00	30.77	5.00	25.00	-	66.67	12.50	62.50	58.33	37.50	-
	C. octofasciatus																	
A.	10	7	24	16	3	14	5	3	15	3	6	8	7	11	10	13	19	20
B.	2	1	2	2	1	3	2	-	5	1	-	-	-	4	2	1	3	2
C.	20.00	14.29	8.33	12.50	33.33	21.43	40.00	-	33.33	33.33	-	-	-	36.36	20.00	7.69	15.79	10.00

Contd.....

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
	Chaetodon trifasciatus																	
A.	8	11	8	16	10	-	-	7	4	5	6	12	10	-	11	15	2	-
B.	-	-	2	3	1	-	-	4	2	2	3	7	5	-	7	6	-	-
C.	-	-	25.00	18.75	10.00	-	-	57.14	50.00	40.00	50.00	58.33	50.00	-	63.64	40.00	-	-
	Cheilioinermis																	
A.	3	12	7	8	7	5	-	-	6	2	3	4	5	9	7	8	1	5
B.	3	9	6	5	-	-	-	-	2	-	1	4	3	8	6	5	-	-
C.	100.00	75.00	85.71	62.50	-	-	-	-	33.33	-	33.33	100.00	60.00	88.89	85.71	62.50	-	-
	Chrysiptera unimaculata																	
A.	9	14	12	5	6	18	4	4	13	10	11	16	15	2	8	5	5	12
B.	3	6	8	2	3	3	1	-	-	10	2	6	6	-	-	4	1	3
C.	33.33	42.86	66.67	40.00	50.00	16.67	25.00	-	-	100.00	18.18	37.50	40.00	-	-	80.00	20.00	25.00
	Dascyllus trimaculatus																	
A.	8	12	13	24	9	-	-	10	13	12	18	26	15	7	16	10	15	-
B.	2	3	5	16	7	-	-	7	7	5	12	11	2	-	12	7	4	-
C.	25.00	25.00	38.46	66.67	77.78	-	-	70.00	55.85	41.67	66.67	42.31	13.33	-	75.00	70.00	26.67	-
	Gnathodentex aureolineatus																	
A.	11	8	3	12	15	2	3	14	5	6	16	20	5	2	15	7	10	3
B.	2	6	1	9	-	-	-	9	5	6	3	-	-	1	8	4	-	-
C.	18.18	75.00	33.33	75.00	-	-	-	64.29	100.00	100.00	18.74	-	-	50.00	53.33	57.14	-	-

Contd.....

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
	Halichoeres scapularis																	
A.	7	8	8	9	10	8	15	13	9	16	26	5	12	15	19	8	9	10
B.	3	5	1	7	7	5	9	8	3	10	23	4	3	11	12	5	5	4
C.	42.86	62.50	12.50	77.78	70.00	62.50	60.00	61.54	33.33	62.50	88.46	80.00	25.00	73.33	63.16	62.50	55.56	40.00
	Lutjanus gibbus																	
A.	3	5	9	8	3	-	-	7	9	12	15	3	17	8	4	-	12	-
B.	2	3	3	2	-	-	-	4	5	5	-	-	4	3	2	-	3	-
C.	66.67	60.00	33.33	25.00	-	-	-	57.14	55.56	41.67	-	-	23.53	37.50	50.00	-	25.00	-
	Lutjanus kasmira																	
A.	18	5	16	3	17	5	3	12	10	23	26	15	13	10	20	8	9	4
B.	12	2	11	-	-	4	-	-	-	15	14	9	7	3	-	-	4	-
C.	66.67	40.00	68.75	-	-	80.00	-	-	-	65.22	53.85	60.00	53.85	30.00	-	-	44.44	-
	Melichthys indicus																	
A.	7	-	6	3	9	2	4	8	16	3	2	4	6	13	12	9	3	1
B.	-	-	-	2	6	-	-	-	9	3	1	-	-	8	-	5	3	-
C.	-	-	-	66.67	66.67	-	-	-	56.25	100.00	50.00	-	-	61.54	-	55.56	100.00	-
	Mulloides flavolineatus																	
A.	15	3	10	27	6	-	4	13	8	17	12	-	10	13	24	5	2	-
B.	2	1	8	19	4	-	-	-	-	9	4	-	4	2	9	2	-	-
C.	40.00	33.33	80.00	70.37	66.67	-	-	-	-	52.94	33.33	-	40.00	15.38	37.50	40.00	-	-

Contd.....

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
	Myripristis murdjan																	
A.	16	8	12	9	25	2	-	-	15	9	7	13	18	6	10	18	20	-
B.	7	-	4	5	12	-	-	-	1	-	3	9	7	-	1	8	8	-
C.	43.75	-	33.33	55.56	48.00	-	-	-	6.67	-	42.86	69.23	38.89	-	10.00	44.44	15.00	-
	Neoniphon sammara																	
A.	-	3	17	12	9	3	-	13	6	9	10	15	20	20	12	11	15	3
B.	-	2	11	9	3	-	-	-	-	-	6	10	-	13	7	9	9	-
C.	-	66.67	64.71	75.00	33.33	-	-	-	-	-	60.00	66.67	-	65.00	58.33	81.82	60.00	-
	Paracirrhites forsteri																	
A.	2	4	10	6	3	-	-	2	9	6	9	-	13	4	12	-	9	-
B.	1	1	4	3	1	-	-	-	-	6	5	-	8	-	7	-	-	-
C.	50.00	25.00	40.00	50.00	33.33	-	-	-	-	100.00	55.56	-	61.54	-	58.33	-	-	-
	Parupeneus barberinus																	
A.	13	5	19	19	9	3	4	5	2	10	7	11	17	6	7	15	14	3
B.	8	1	11	7	1	-	-	-	-	3	2	-	10	-	2	9	7	1
C.	61.54	20.00	57.89	36.84	11.11	-	-	-	-	30.00	28.57	-	58.82	-	28.57	60.00	50.00	33.33
	P. bifasciatus																	
A.	6	3	9	10	2	-	3	8	18	11	12	3	7	13	5	7	4	2
B.	2	-	7	4	1	-	-	-	8	7	2	-	5	8	2	3	-	-
C.	33.33	-	77.78	40.00	50.00	-	-	-	44.44	63.64	16.67	-	71.43	61.54	40.00	42.86	-	-

Contd.....

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN
	Plectorhinchus orientalis																	
A.	8	3	6	14	9	-	-	-	11	10	9	2	15	9	2	6	5	-
B.	-	-	-	9	3	-	-	-	-	-	-	1	9	-	1	4	1	-
C.	-	-	-	64.29	33.33	-	-	-	-	-	-	50.00	60.00	-	50.00	66.67	20.00	-
	Pomacentrus pavo																	
A.	13	10	26	38	13	11	18	24	20	23	18	17	12	10	34	16	33	16
B.	9	3	21	19	5	2	3	6	9	8	3	9	-	-	16	12	26	7
C.	69.23	30.00	80.77	50.00	38.46	18.18	16.67	25.00	45.00	34.78	16.67	52.94	-	-	47.06	75.00	78.79	43.75
	Rhinecanthus aculeatus																	
A.	10	6	7	10	18	5	8	8	5	4	9	14	13	3	16	13	14	3
B.	1	-	2	6	5	-	-	1	2	1	2	5	6	-	-	8	3	-
C.	10.00	-	28.57	60.00	27.78	-	-	12.50	40.00	25.00	22.22	35.71	46.75	-	-	61.54	21.43	-
	Thalassoma hardwicki																	
A.	8	8	9	11	4	3	6	12	15	3	18	9	11	17	6	2	1	5
B.	-	5	5	9	3	-	-	-	9	2	18	7	-	9	3	2	-	-
C.	-	62.50	55.56	81.82	75.00	-	-	-	60.00	66.67	100.00	77.78	-	52.94	50.00	100.00	-	-
	Thalassoma lunare																	
A.	5	8	16	2	7	-	-	3	4	6	12	2	4	11	13	4	2	-
B.	1	5	6	-	3	-	-	-	-	2	8	-	3	5	9	1	-	-
C.	20.00	62.50	37.50	-	42.86	-	-	-	-	33.33	66.67	-	75.00	45.45	69.23	25.00	-	-

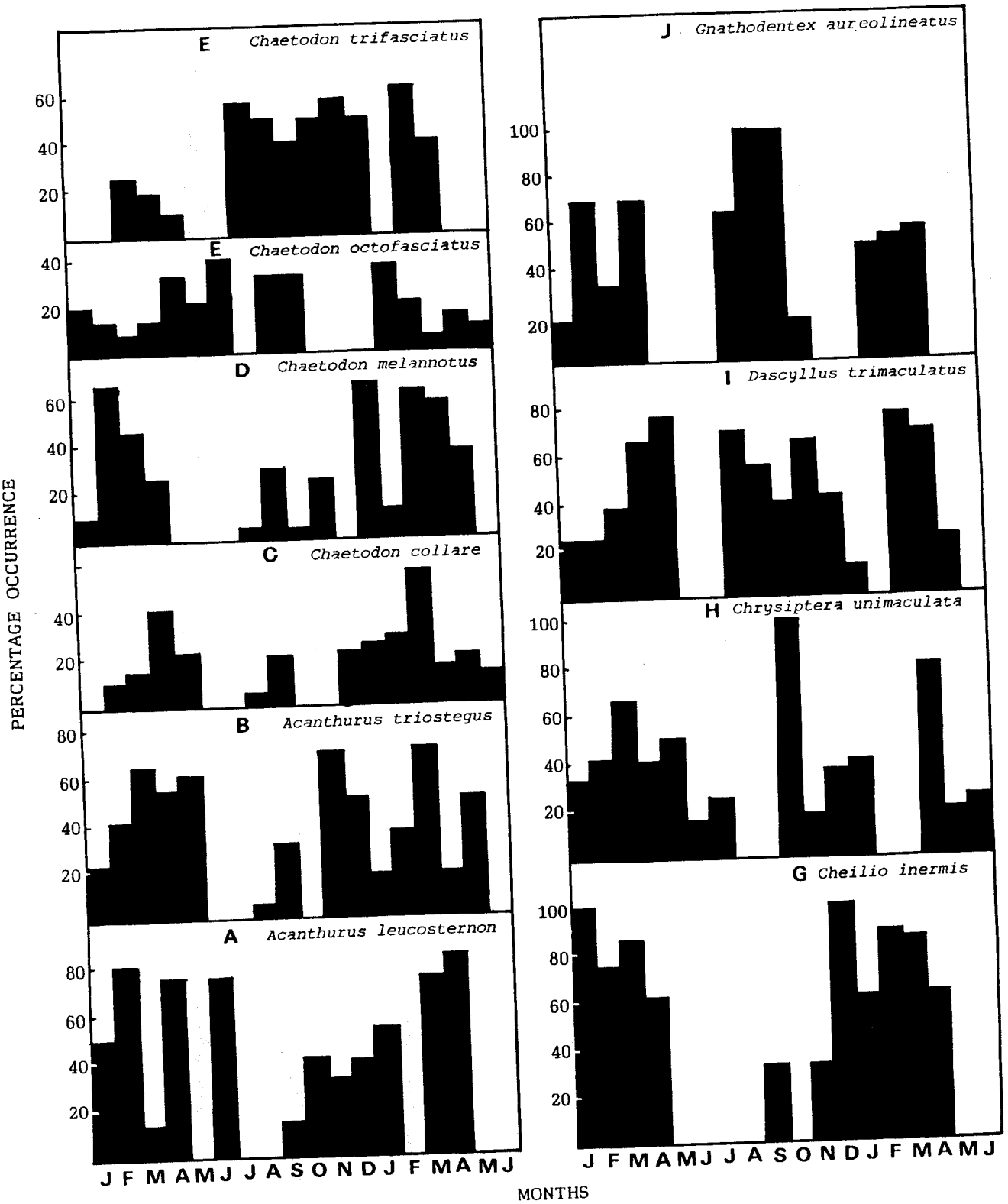

Figure 50. Percentage occurrence of ripe individuals of 10 coral reef fishes (A to J) from January 1991 to June 1992.

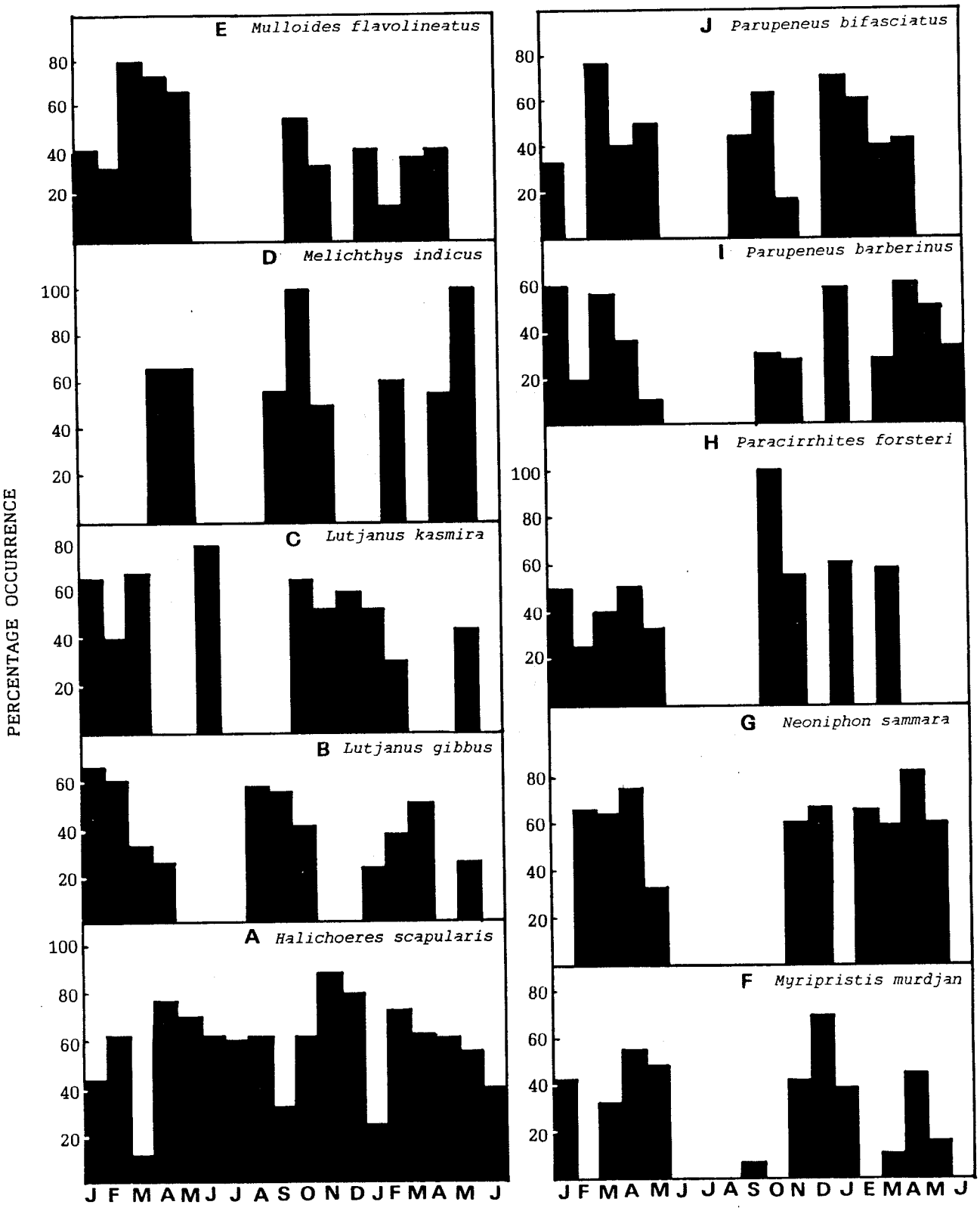

Figure 51. Percentage occurrence of ripe individuals of 10 coral reef fishes (A to J) from January 1991 to June 1992.

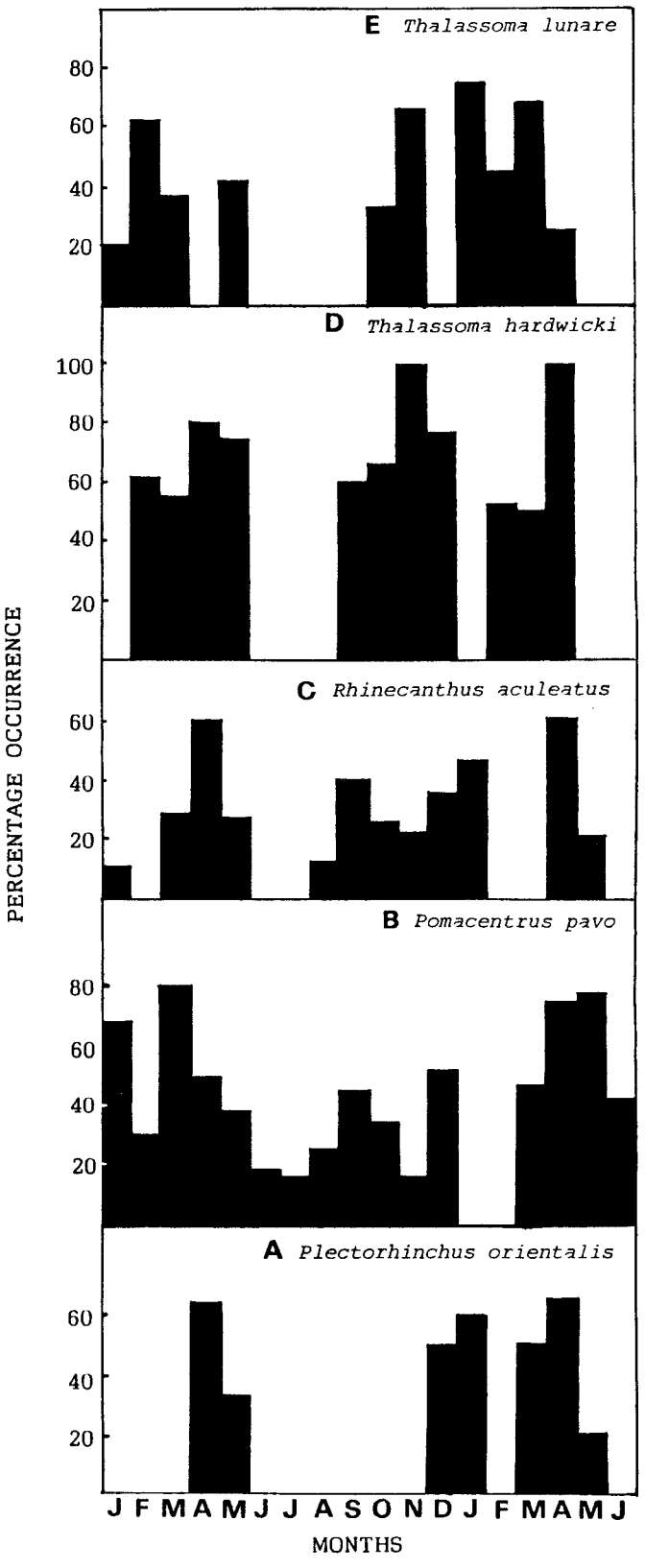

Figure 52. Percentage occurrence of ripe individuals of five coral reef (A to E) fishes from January 1991 to June 1992.

The ova diameter frequency polygon shows three groups of ova with modes at 0.35, 0.54 and 0.74 mm. The species is likely to spawn with short intervals since the modes are separated. The largest ova measured 0.74 mm (Fig 49 I).

Spawning individuals occurred in high proportions in February '91 (62.50%) November (66.67%), January '92 (75.00%) and March (69.23%). In general, spawning individuals were observed for a prolonged period from January to May and a short period during October and November (33.33 and 66.67%). Spawning individuals were not observed in June, July, August and September (Table 67, Fig 52 E).

B. OCCURRENCE OF JUVENILES ON SEAGRASS BEDS

Information on the monthly abundance, size ranges, total abundance and percentage abundance of juveniles belonging to each of the 28 reef fish families collected on seagrass beds are given in this account (Table 68). Also presented are, details on monthly variation of all juveniles and the effects of salinity temperature and moon phases on their occurrence.

1. Juvenile representation (family-wise) on seagrass beds.

a. Acanthuridae: Acanthurids contributed to the highest juvenile abundance recording 316 post-larval stages forming 13.62% of juveniles from seagrass beds. They occurred in size ranges between 18 and 72 mm. Maximum number of individuals were recorded in January, February and September (39, 43 and 41 nos respectively) while least

counts were observed during the monsoon months of May, June, July and August with 20, 12, 21 and 17 nos respectively (Fig 53 A, Photo 60).

b. Apogonidae: 106 juvenile apogonids forming 4.57% of juveniles were recorded. They occurred in size ranges between 15 and 52 mm. Higher counts were registered in May (17 nos) and September (19 nos) while the least were recorded in March, June and July (3, 3 and 2 nos). Apogonid juveniles generally occurred in all months (Fig 53 B).

c. Balistidae: Only 12 balistid juveniles (0.52%) were observed in the size range of 43 to 64 mm recording one to three individuals. They were generally rare on seagrass beds.

d. Carangidae: Juvenile carangids formed one of the dominant groups on seagrass beds recording a total of 190 individuals (8.19%). Common size ranges were between 75 and 100 mm with maximum counts observed in March, April and August (31, 41 and 45 nos respectively). Only 2 individuals were recorded in June, and the occurrence of this group was seasonal (Fig 53 C).

e. Chaetodontidae: 121 chaetodontids forming 5.22% of juveniles were recorded in sizes between 14 and 62 mm. Juvenile counts were high in March, July and December (15, 14 and 15 nos respectively) while it was least in February, August and October (6, 6 and 5 nos respectively). Juveniles of Chaetodon auriga, C. falcula, C. lunula, C. melannotus and C. trifascatus were commonly observed round the year while young of other species were rare (Fig 53 D, Photo 61).

f. Diodontidae: 20 juveniles (0.86%) in the size range of 80 to 88 mm belonging to Diodon histrix were recorded. Juvenile representation of this family on seagrass beds was rare.

g. Platacidae: Only 6 juveniles (0.26%) measuring between 80 to 89 mm were recorded.

h. Exocoetidae: 42 juveniles (1.81%) in the size range of 40 to 45 mm were recorded with maximum counts in July and October (10 and 19 nos). Occurrence was rare and seasonal.

i. Fistulariidae: 92 juvenile fistulariids (3.24%) in the size range of 120 to 160 mm were recorded. Maximum counts were observed in April (15 nos), July (18 nos) and October (15 nos). Juveniles belonging to Fistularia petimba were common on seagrass beds.

j. Haemulidae: 6 juveniles (0.26%) in the size range of 100 to 110 mm were observed. Occurrence was rare.

k. Hemiramphidae: 79 juvenile hemiramphids (3.41%) in the size ranges of 80 to 123 mm were observed with maximum counts (17 nos) in February. Occurrence of juveniles was seasonal.

l. Holocentridae: 147 juveniles (6.34%) in the size range of 32 to 83 mm were observed. Maximum counts were registered in January, February and April (21, 19 and 19 respectively) while a least count (3 nos) was recorded in May. Juveniles mainly composed of Myripristis murdjan, M. adusta and Neoniphon sammara (Fig 53 E).

m. Kuhlidae: 21 juveniles (0.91%) measuring between 50 and 75 mm were observed. Occurrence of juveniles was seasonal and rare.

n. Labridae: Labrids contributed significantly to juvenile abundance on seagrass beds recording 250 nos accounting for 10.78%. They occurred in sizes between 12 to 64 mm with maximum counts observed in March and April (45 and 41 nos) while a least count was recorded in May (9 nos). Labrids were observed in all months and particularly dominant were juveniles of Halichoeres scapularis and Stethojulis spp. (Fig 54 A).

o. Lethrinidae: 79 individuals (3.41%) in the size range of 20 to 65 mm were recorded. Maximum counts were observed in January (16 nos) while a least count occurred in November (2 nos). Juveniles were present in almost all months.

p. Lutjanidae: Lutjanid juveniles were relatively abundant on seagrass beds recording 123 individuals (5.30%) in the size range of 30 to 83 mm. They occurred in higher numbers in January April, July, and October (20, 16, 17 and 18 nos respectively) while least counts were observed in March and November (2 nos each). Juveniles generally occurred round the year with the dominant species being Lutjanus kasmira and L. bohar (Fig 54 B).

q. Mugilidae: 23 individuals (0.99%) in the size range of 70 to 75 mm were observed. Maximum counts were recorded in August (11 nos). Juveniles occurred seasonally.

r. Mullidae: Juveniles of mullids were observed in relatively more numbers recording 156 individuals (6.72%) in the size range of 28 to

64 mm. Counts were high in January (31 nos) while it was least in August (3 nos). Juveniles of Parupeneus pleurostigma were particularly dominant, though other species were also common round the year (Fig 54 C).

s. Muraenidae: 61 muraenids (2.63%) in the size range of 80 to 150 mm were observed. Highest count was registered in January (12 nos). Juveniles were seasonal and rare on seagrass beds, with the dominant species being Gymnothorax undulatus.

t. Pemphiridae: 16 juveniles (0.69%) in the size range of 50 to 70 mm were observed. Juvenile pemphrids were rare on seagrass beds.

u. Pomacanthidae: Only two individuals measuring between 80 to 82 mm were recorded. Juveniles were rare on seagrass beds.

v. Pomacentridae: 24 juveniles (1.03%) were recorded in the size range of 18 to 43 mm. Young fish of Abudefduf sexfasciatus only were found and were rare on seagrass beds.

w. Scardiae: Scarids were observed to form one of the dominant groups of juveniles on seagrass beds recording 157 nos (6.77%) in the size range of 30 to 83 mm, counts were high in August (23 nos) while it was least in March (2 nos). In general, scarid juveniles occurred on seagrass beds in all months (Fig 54 D).

x. Scorpaenidae: 18 individuals (0.78%) in the size range of 60 to 100 mm were recorded. Juveniles were rare on seagrass beds.

y. Serranidae: 61 individuals (2.63%) in the size range of 40 to 83 mm were recorded. Juveniles were rare on seagrass beds (Photo 62).

z. Siganidae: 157 individuals (6.77%) were observed in the size range of 30 to 82 mm. Maximum counts were recorded in December (38 nos) while least counts were observed in April, June and August (4, 3 and 3 nos respectively). Juveniles were recorded in all months (Fig 54 E, Photo 63).

aa. Sphyraenidae: 17 Juveniles (0.73%) in the size range of 60 to 90 mm were recorded and were rare on seagrass beds.

ab. Tetraodontidae: 34 juveniles (1.47%) in the size range of 50 to 120 mm were recorded and were rare on seagrass beds.

The most dominant families that occurred on seagrass beds in their juvenile stages were Acanthuridae, Apogonidae, Carangidae, Chaetodontidae, Holocentridae, Labridae, Lutjanidae, Mullidae, Scaridae and Signidae. Of these 10 families Acanthuridae, Carangidae and Labridae were abundant. Pomacentridae indicated least counts followed by Haemulidae and Platacidae (Fig 55).

2. Seagrass beds as fish nurseries: Ecological processes observed with regard to juvenile coral reef fishes on seagrass beds are described in Fig. 56. Seagrass beds act as nurseries for new recruits, post-larvae and juvenile fishes (Photo 64). The 'nursery phase' with direct dependents on seagrass beds consisted of newly settled postlarvae and advanced juveniles, macroplankton mainly composed of crustaceans, other

Table 68. Month-wise number (N), size range (SR), total number of juveniles of a family (TN), percentage (%) and total number of juveniles of all families on seagrass beds from January to December 1991.

	FAMILY	JAN,	NM	FEB,	NM	MAR,	FM	APR,	NM	MAY,	FM	JUN,	NM	JUL,	FM	AUG,	FM	SEP,	NM	OCT,	NM	NOV,	FM	DEC,	NM		
		N	SR	N	SR	N	SR	N	SR	N	SR	N	SR	N	SR	N	SR	N	SR	N	SR	N	SR	N	SR	TN	%
1.	Acanthuridae	39	22-72	43	22-64	21	30-36	32	20-63	20	22-70	12	25-63	21	22-36	17	20-24	41	20-63	30	22-54	14	18-43	26	20-54	316	13.62
2.	Apogonidae	12	22-43	7	40	3	26	10	38-45	17	15-45	3	30	2	25	10	40-52	19	24-42	10	20	-	-	13	43	106	4.57
3.	Balistidae	1	60	-	-	-	-	3	43	-	-	1	52	-	-	2	64	3	46	-	-	-	-	2	54	12	0.52
4.	Carangidae	17	100	12	84	31	82	41	75	13	100	2	75	-	-	45	84	16	100	-	-	-	-	13	85	190	8.19
5.	Chaetodontidae	11	24-59	6	39	15	42	10	15-33	10	45-60	10	14-35	14	18-38	6	40	9	14-48	5	20-62	10	42	15	14-35	121	5.22
6.	Diodontidae	2	83	-	-	-	-	5	30	7	55	-	-	-	-	3	65	-	-	-	-	3	73	-	-	20	0.86
7.	Platacidae	-	-	1	89	-	-	5	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	0.26
8.	Exocoetidae	-	-	1	40	-	-	9	45	-	-	-	-	10	40	-	-	-	-	19	40	-	-	3	40	42	1.81
9.	Fistulaiidae	-	-	6	123-160	6	133	15	120-144	-	-	-	-	18	120-149	-	-	4	140	15	122-160	2	145	10	120	76	3.24
10.	Haemulidae	-	-	-	-	-	-	2	110	2	110	-	-	-	-	-	-	-	-	2	100	-	-	-	-	6	0.26
11.	Hemiramphidae	3	90	17	96	8	98	-	-	7	100-123	3	90	13	83	12	100	3	80	13	98	-	-	-	-	79	3.41
12.	Holocentridae	21	42-80	19	67-73	13	34-78	19	45-80	4	32-80	10	53	7	35-50	7	34-80	11	60-73	6	40-68	13	43	17	75-83	147	6.34
13.	Kuhlidae	3	63	-	-	-	-	2	70	2	75	-	-	-	-	-	-	3	50	6	63	-	-	5	55	21	0.91
14.	Labridae	10	12-52	23	12-40	45	20-52	41	24-64	9	12-50	11	12-45	19	14-35	15	36-52	22	20-58	24	12-55	19	12-50	12	25-32	250	10.78
15.	Lethrinidae	16	28-40	6	38	9	2046	13	40	5	43-65	2	20-40	-	-	9	40	9	35	-	-	2	20	8	28-43	79	3.41
16.	Lutjanidae	20	34	-	-	2	30	16	83	6	55	8	58	17	35	9	43	13	58	18	55	2	46	12	42	123	5.30
17.	Mugilidae	-	-	-	-	1	75	4	75	4	70	-	-	3	70	11	75	-	-	-	-	-	-	-	-	23	0.99
18.	Mullidae	31	28-64	19	39-53	17	48-56	12	39-50	7	63	16	39	7	48-60	3	30	12	35-52	14	48-56	-	-	18	42	156	6.72
19.	Muraenidae	12	82-100	4	80	7	80	3	120-150	-	-	-	-	9	120-150	15	100	8	100-150	3	120-150	-	-	-	-	61	2.63
20.	Pemphridae	-	-	3	50	-	-	9	70	-	-	-	-	2	70	2	50	-	-	-	-	-	-	-	-	16	0.69
21.	Pomacanthidae	-	-	-	-	-	-	-	-	-	-	1	82	-	-	1	80	-	-	-	-	-	-	-	-	2	0.09
22.	Pomacentridae	-	-	-	-	-	-	-	-	2	30	6	30-43	-	-	9	18-25	2	30	3	25	-	-	2	25	24	1.03
23.	Scaridae	15	34-62	16	34-70	2	34-54	14	50-83	17	30-54	10	34-58	17	38-60	23	50-69	10	25-53	15	34-70	7	38	11	50	157	6.77
24.	Scorpaenidae	2	83	-	-	-	-	1	100	-	-	-	-	3	100	2	80	1	60	9	73	-	-	-	-	18	0.78
25.	Serranidae	3	42	8	44	1	67	6	42	-	-	-	-	12	40	-	-	7	83	9	58.72	3	42	12	44	61	2.63
26.	Siganidae	16	30-79	12	42-82	17	42-80	4	45-80	8	52	3	30	8	40-75	3	46-75	17	64	11	74	20	60	38	64-80	157	6.77
27.	Sphyraenidae	2	84	1	60	-	-	-	-	4	85-90	-	-	-	83	-	-	-	-	3	69	-	-	4	65	17	0.73
28.	Tetraodontidae	-	-	-	-	-	-	-	-	9	65	-	-	6	80	-	-	-	-	3	79	10	50-110	6	54-120	34	1.47
Total		236		204		198		276		153		98		191		204		210		218		105		227		2320	

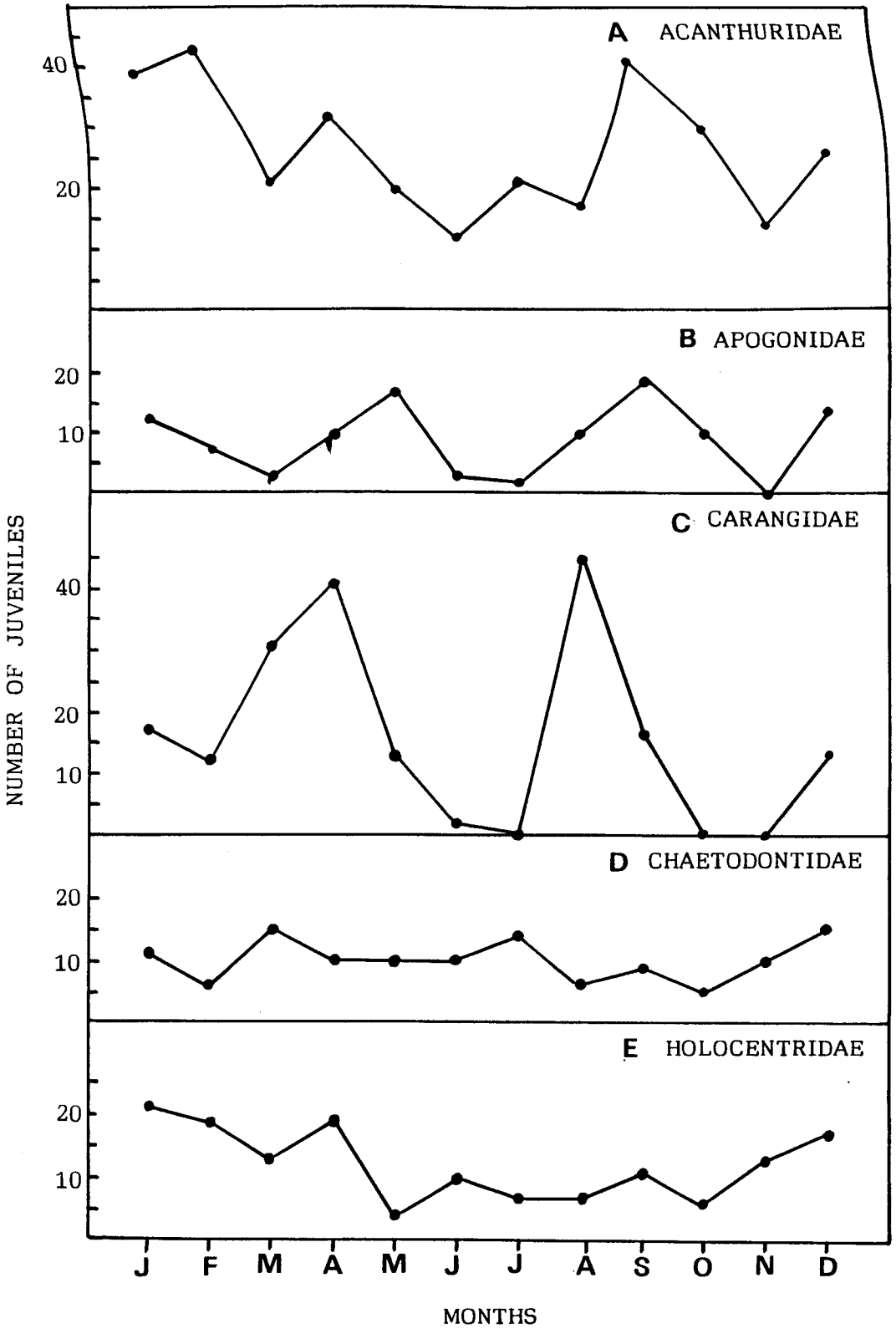

Figure 53. Month-wise occurrence of juveniles of five families recorded on (A to E) seagrass beds from January to December 1991.

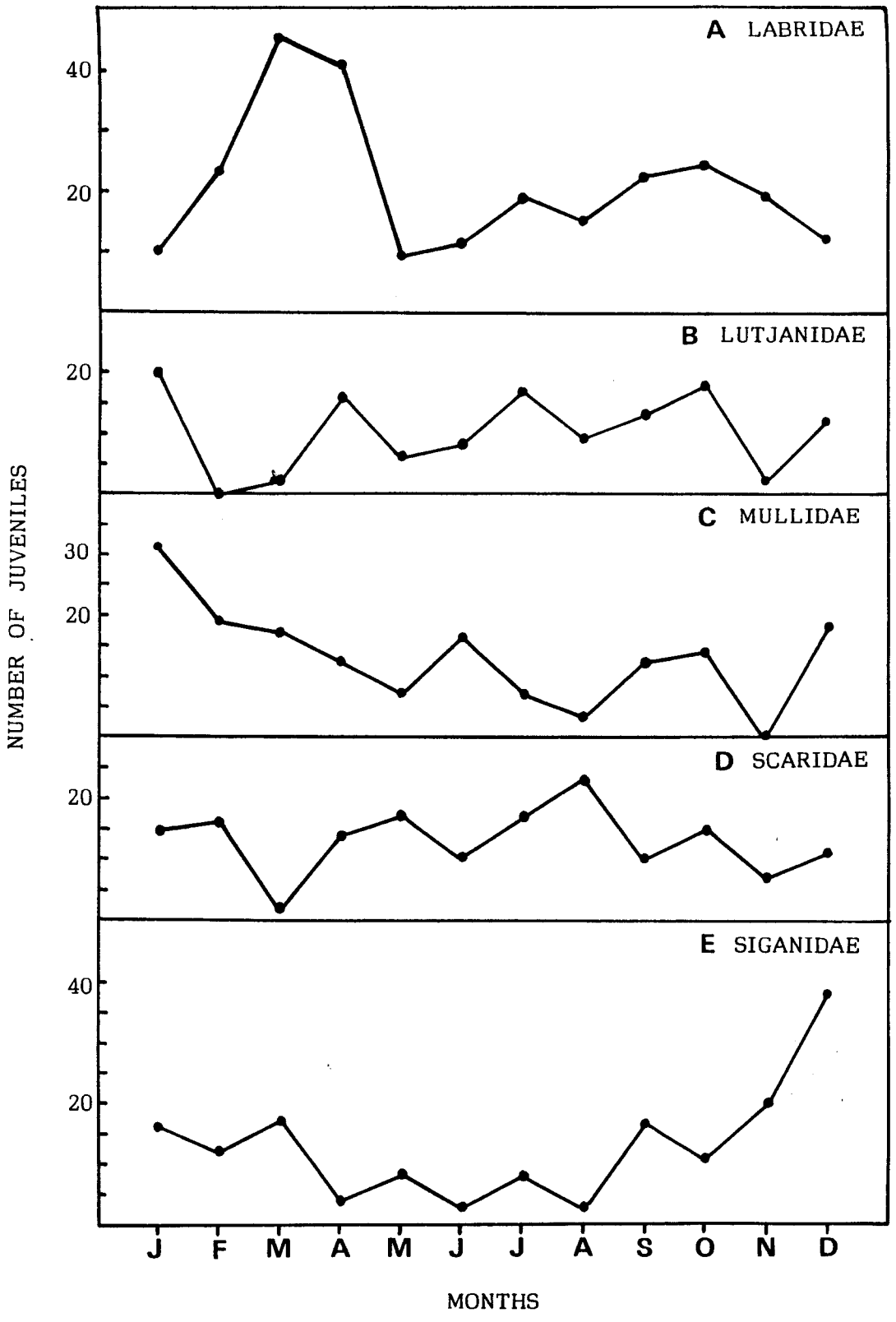

Figure 54. Total number of juveniles of five families recorded on seagrass (A to E) beds from January to December 1991.

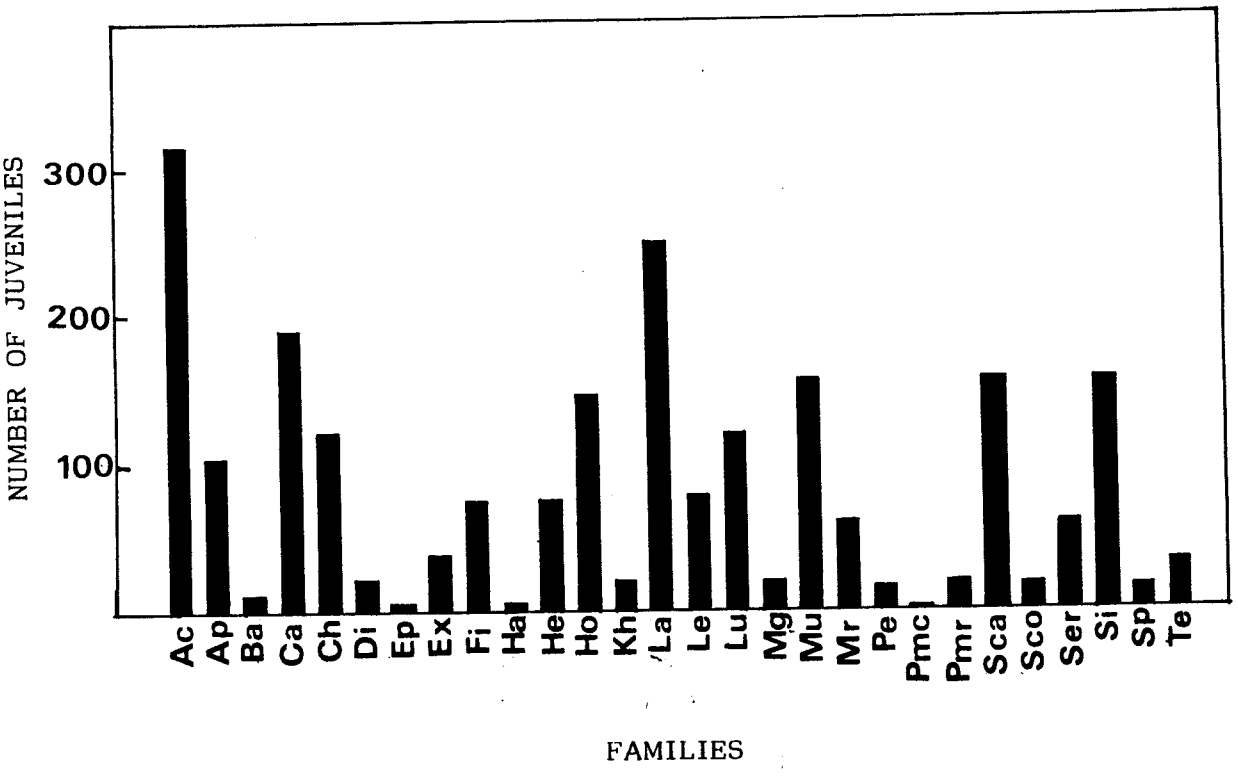

Figure 55. Abundance of juveniles of various families on seagrass beds (January to December 1991).

(Ac - Acanthuridae, Ap - Apogonidae, Ba - Balistidae, Ca - Carangidae, Ch - Chaetodontidae, Di - Diodontidae, Pl - Platacidae, Ex - Exocoetidae , Fi - Fistularidae, Ha - Haemulidae, He - Hemiramphidae, Ho - Holocentridae, Kh - Kuhlidae, La - Labridae, Le - Lethrinidae, Lu - Lutjanidae, Mg - Mugilidae, Mu - Mullidae, Mr - Muraenidae, Pe - Pemphridae, Pmc - Pomacanthidae, Pmr - Pomacentridae, Sca - Scaridae, Sco Scorpaenidae, Ser - Serranidae, Si - Siganidae, Sp - Sphyraenidae, Te - Tetraodontidae).

invertebrates (Photo 65) and more - and macro - algal components. Considering juvenile fishes at the highest trophic level and trapped nutrients in seagrass beds at the lowest level a small food chain is evident. Seagrasses act as a safe habitat for young fishes and they generally occur on shallow waters in Lakshadweep. Large predators normally keep away from shallow waters.

In the 'transitional phase' juveniles migrate from seagrass beds to adult habitats (rubble, massive coral, live coral etc.) after they have transformed enough to cope up with 'an outer world' with regard to food, competitors, predator escape and shelter. As observed from size ranges of juveniles, fish beyond a certain size were not observed indicating that their association with seagrass beds is only temporary.

Seagrass beds form a component of the food chain. Sub-adult predators frequent the area at night in search of food (fish and macroplankton) while most herbivorous fish feed on seagrass and associated algae directly during day.

Reproduction generally takes place around adult habitats that have desirable water depths and influence of currents. Information on planktonic stages of reef fish is scarce and they presumably occur in the vicinity of reef extending upto a few kilometers. No attempts were made to track this phase. The larvae metamorphose and settle on various habitats of which seagrass beds are important.

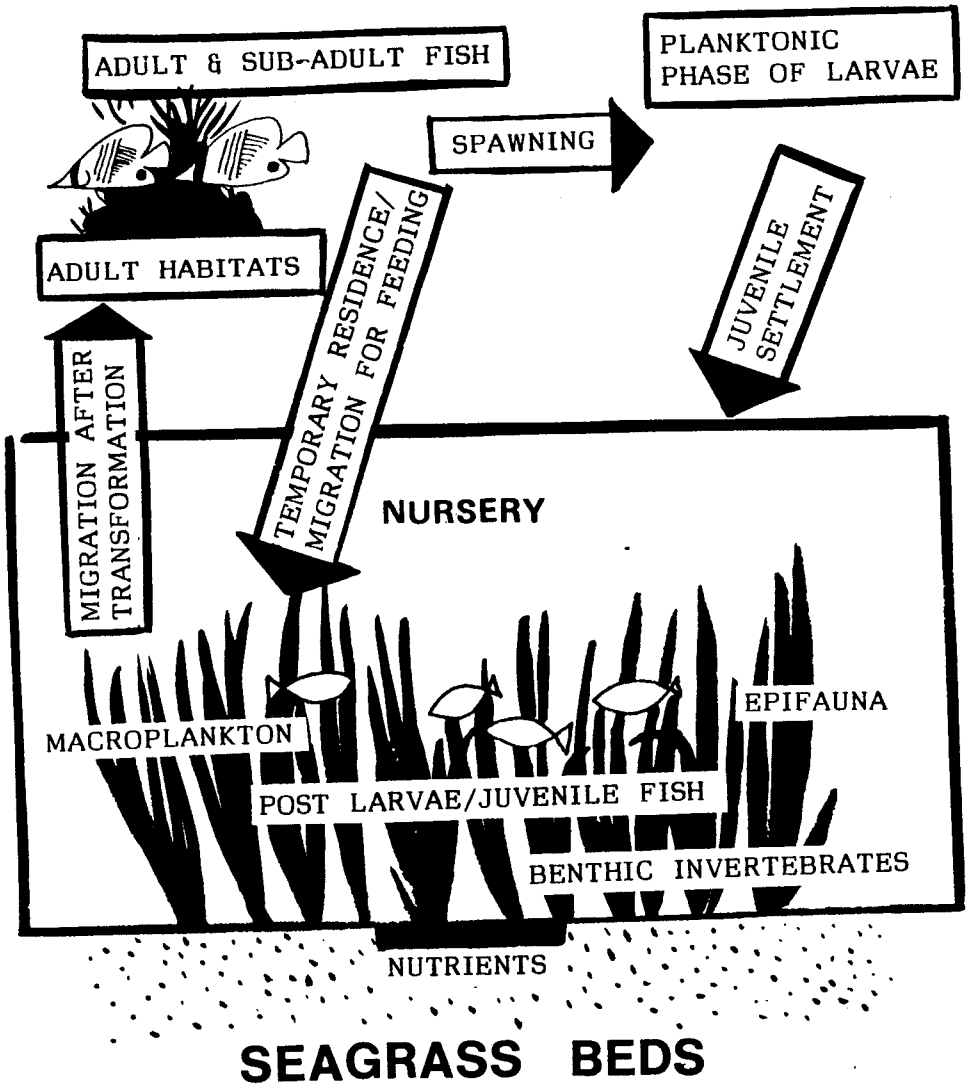

Figure 56. Ecological process concerning juveniles on seagrass beds.

3. Monthly juvenile abundance: Figure 57 shows monthly juvenile abundance on seagrass beds. Total juvenile counts were highest in April (276 nos) and January (236 nos). Relatively more juveniles were observed in December (227 nos). February, August, September and October recorded counts above 200 individuals (204, 204 and 210 respectively). Lowest number of juveniles were recorded in June (98 nos). Juvenile abundance in March and July were comparable (198 and 191 nos) respectively. May and November registered counts of 153 and 105 individuals respectively.

4. Effect of temperature and salinity on juveniles: Effect of salinity on juvenile abundance on seagrass beds was found to be significant at 5% level while that of temperature on abundance was not significant. An increase in salinity regime in the area was observed with increase in juvenile fish while there existed no relationship between temperature and abundance. At the highest temperature (32.00°C), 227 individuals were recorded while at a temperature of 30.00°C the maximum number of 276 individuals were recorded (Table (69).

5. Effect of moon phases on juvenile abundance: Juvenile abundance between moon phases (new and full moon) was found to be significant when the least count of 98 individuals was omitted for calculation pruposes. In general the new moon phase (dark nights) recorded higher juvenile counts (204 to 276 nos) while the full moon phase (bright nights) recorded relatively lower counts between 105 and 204 individuals (Table 70).

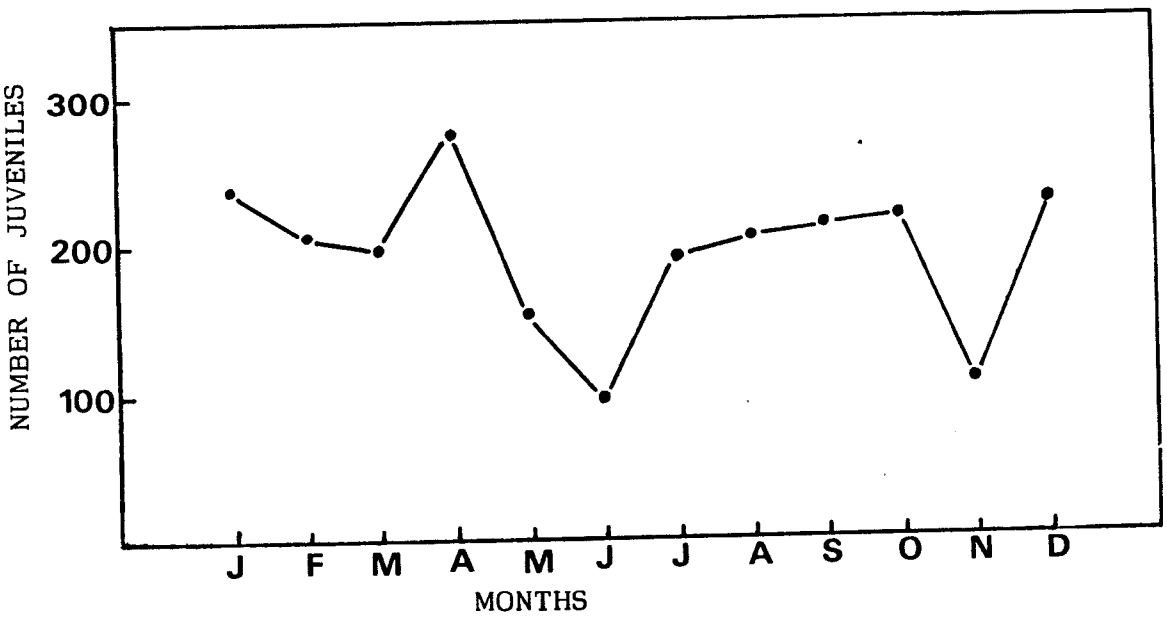

Figure 57. Month-wise occurrence of all juveniles on seagrass beds during a 12 - month period (January to December 1991).

Table 69. Month-wise total number of juveniles against salinity and temperature from January to December 1991 on seagrass beds (values in paranthesis indicate ranks).

Month	Salinity ppt	Temperature °C	Total juveniles
January	34.65 (4)	28.50 (6)	236 (2)
February	33.00 (12)	28.00 (8)	204 (6.5)
March	34.0 (6.5)	30.70 (2)	198 (8)
April	36.00 (2)	30.00 (4)	276 (1)
May	33.80 (9)	29.50 (5)	153 (10)
June	33.60 (10)	28.10 (7)	98 (12)
July	33.90 (8)	26.30 (11)	191 (9)
August	33.50 (11)	26.20 (12)	204 (6.5)
September	36.40 (1)	27.50 (9)	210 (5)
October	34.60 (5)	27.30 (10)	218 (4)
November	34.00 (6.5)	30.60 (3)	105 (11)
December	35.20 (3)	32.00 (1)	227 (3)

Rank correlation values:

Salinity x abundance	- 0.647	Degrees of freedom-10	Significant at 5% level
Temperature x abundance	- 0.065	Degrees of freedom-10	not significant

Table 70. Total number of juveniles recorded on seagrass beds from January to December 1991 on new moon and full moon phases.

New moon	Full moon
236	198
204	153
276	191
98	204
210	105
218	
227	

Calculated values (ANOVA): The value '98' has been avoided for calculation purpose.

New moon		Full moon
n	6	5
x	228.5	170.20
Σx	1371.00	851.00
Σx^2	316,641.00	151,735.00

	Degrees of freedom	Sum of squres	Mean sum of squares	F value
Between phases	1	9269.70	9269.70	8.13 *
Within phases	9	10262.30	1140.26	
Total	10	19532.00		

* Significant

DISCUSSION

Reproduction in reef fishes is known to be complex. This account deals with the diversity in aspects of maturity and spawning of few species studied and occurrence of juveniles on seagrass beds. Warner (1991) stated that life histories and sexual patterns are diverse with mature individuals occuring over a great range of sizes, and that average longevities range from a few months to many years. Some species are heterosexual, others show change in sex while some others are hermaphrodites.

Size at first maturity and sex-ratio.

Both females and males of Acanthurus leucosternon were found to attain maturity in the size range of 101 to 110 mm SL. Maturation process in females seemed to prolong up to a SL of 120 mm. In general, this species appeared to mature at relatively smaller sizes as compared to the maximum size obtained in this study (151 to 160 mm). Reeson (1983) found A. coeruleus to mature at about 13 cm FL and A. bahianus at about 11 cm FL. Though length measures, species and the geographic area (Caribbean region) vary from the present study, their size at first maturity appears to be similar to that of A. leucosternon. Further, Reeson (1983) reported that sexes are separate amongst the acanthurids and found no evidence of sexual dimorphism. The sex-ratio of 1:1 (female : male) in the present study possibly supports the fact. In contrast to A. leucosternon, A. triostegus matured at an even smaller size range (81 to 90 mm), perhaps due to a relatively smaller size attained by this species.

The four chaetodontid species recorded were found to mature between 61 to 100 mm SL. Burgess (1978) observed that according to maximum standard length of the various species, specimens in the size range below 40 to 60 mm SL were considered as juveniles. In the present study, size ranges of Chaetodon melannotus and C. octofasciatus are in accordance with the observation of Burgess (1978) and could be termed juveniles as sex was indeterminate below 60 mm, while in C. collare and C. trifasciatus it was below 80 and 70 mm SL respectively. Sizes at first maturity in all the 4 species appeared to be closer to maximum sizes collected in the present study. Ralston (1976) and Tricas (1986) stated that by the time of sexual maturity at approximately one year of age, butterflyfishes reached 70% to 75% of their maximum size; similar observations were made in the present study. Size at first maturity for Chaetodon collare and C. trifasciatus occurred at relatively larger lengths (91 to 100 mm and 81 to 90 mm size groups respectively) compared to C. melannotus and C. octofasciatus (71 to 80 mm size group). Males and females matured sinchronously except in C. collare where males matured later (101 to 110 mm). As pair formation in butterflyfishes is a well known fact (Fricke, 1986) synchronous maturity of males and females is perhaps advantageous for reproductive success. C. collare was always observed in groups of 5 to 10 individuals and pair bonding did not appear to be strong. This could probably explain the differential maturity in males and females. All chaetodontids studied were dominated by the number of females except in the case of C. octofasciatus where males dominated. Lobel (1989) found that the sex ratio of mature C. multicinctus collected in pairs was 1:1, while Vijay Anand (1990 a) recorded a ratio of

1:1.70 (male : female). Collection of mature pairs would have yielded a sex-ratio of 1:1 but in the present study pairs were not always effeciently captured, and further the collection of small groups of sub-adults could have varied the ratios.

Larger maturity sizes (121 to 150 mm) in Cheilio inermis is perhaps dependent on its long body feature. Protogyny is strongly developed in Labridae with the occurrence of two types of males namely, the primary and secondary males (Robertson and Choat, 1974; Warner and Robertson, 1978). The males recorded in Cheilio intermis in the present study were perhaps large secondary males (271 to 300 mm) and this cannot be considered as size at first maturity. Inclusion of a few primary males could have helped in determining the maturity size in males. The high difference in the sex-ratio is possibly due to the protogyny that is predominant in labirds. A similar picture was evident in Halichoeres centiquadrus but sizes at which fish matured were smaller (61 to 70 mm). Data indicated the presence of primary and secondary males. However, the sex-ratio pattern reflected on protogyny.

Most pomacentrids are smaller territorial fishes. Early onset of maturity in Chrysiptera unimaculata and Dascyllus trimaculatus (21 to 30 mm and 31 to 40 mm respectively) is possibly due to small body size and these may also be relatively short lived species, males in the former species matured later than females; and females dominated in both species. Pillai and Madan Mohan (1990) reported the size at first maturity of Abudefduf glaucus to be 60 mm TL.

Females of Gnathodentex aureolineatus were dominant and matured earlier than males. The maximum size recorded for G. aureolineatus by Jones and Kumaran (1980) was 165 mm while in present study it was 150 mm. Despite small body size, this species appeared to mature at a relatively later age.

Males of Lutjanus gibbus matured earlier than females. Thompson and Munro (1983) suggested that an early maturity in males of some Caribbean lutjanids could be due to a faster growth rate in males. Apart from this reasoning, it may be possible that females of L. gibbus matured relatively later than males. Fully mature females were recorded above 191 mm while males occurred above 151 mm. Females of L. kasmira were dominant and matured earlier than males. The overall sizes at first maturity appeared to be lower for this species occurring in Lakshadweep as compared to those in Andaman Islands. Rangarajan (1971) found that in the case of L. kasmira from Andamans, maturity sets in at 170 mm and 50% of them were mature at 200 mm. The reasons for this difference remain unclear.

Hermaphroditism, heterosexuality or intersexuality have not been reported in Balistidae (Aiken, 1983). Synchronous maturation of females and males of Melichthys indicus could possibly be attributed to lack of complicated sexuality patterns. Maturity for both sexes was attained between 111 and 120 mm with females as the dominant sex.

Males and females of Mulloides flavolineatus matured at 91 to 110 mm SL and the process appeared to be prolonged upto 130 mm in females.

In comparison to Mulloidichtys martinicus which matured between 175 and 185 mm FL (Munro, 1976), the species in the present study matured at smaller body lengths. The predominance of females of Mulloidichthys martinicus (Munro, 1976) was similar to the sex ratio of 1:0.78 (female : male) in Mulloides flavolineatus.

Males of Myripristis murdjan matured much earlier than females. Fully mature males measured above 81 mm while the same in females was above 131 mm. As these are schooling species and the number of males are relatively less (sex-ratio = 1:0.48, females : male), it would possibly be advantageous for males to mature earlier to ensure reproductive success. In contrast, though the number of males was less in Neoniphon sammara differential maturity did not occur and females were dominant.

Females of Paracirrhites forsteri were dominant and attained maturity at larger sizes (71 to 80 mm) as compared to males (51 to 60 mm). As information on their social systems could not be obtained, no conclusions can be drawn about their sexuality.

Females of Parupeneus barberinus and P. bifasciatus dominated and matured at larger sizes (111 to 130 mm and 91 to 110 mm respectively) compared to males (151 to 170 mm and 131 to 150 mm respectively). Munro (1983) reported that Pseudupeneus maculatus may probably mature at sizes less than 16 cm FL and Mulloidichthys martinicus between 17.50 and 18.50 cm. FL. Though the species under consideration are different, on the basis of the family, Mullidae, these species appear to show similarities in sizes of maturity with a difference of a few millimeters.

Maturity in Plectorhinchus orientalis is reached at larger sizes because of larger lengths attained by the species. The present study recorded a maximum size of 380 mm while Jones and Kumaran (1980) reported maximum size ranges of 280 mm. While females were dominant, males matured later than females.

Pomacentrid maturity patterns have already been discussed. As they are small bodied, short-lived species it is perhaps advantageous for them to mature at smaller sizes and maximise egg production. Such observations were made a Pomacentrus pavo with females as the dominant sex.

In the case of Rhinecanthus aculeatus, males began maturing at an earlier stage (81 mm onwards) and the process appeared to continue till size limits of 130 mm. This indicated that males did not have definite cut-off points for onset and termination of the maturing process. This was not evident in females that dominated the sex-ratio.

Among the two labrids, Thalassoma hardwicki had a faster maturation rate where females matured at 81 to 90 mm while in T. lunare it was between 91 to 100 mm. Wrasses in general appeared to mature at smaller size ranges. T. hardwicki and T. lunare have been reported to exhibit protogynous hermaphroditism and diandry (Robertson and Choat, 1974). Because of the variation in social structure of these fishes, collections might have included fishes in different stages. In the present study, data on males indicated their occurrence above 101 or 131 mm. These are probably larger secondary males. It is likely that primary males occur at smaller sizes and represent diandry (as seen in Halichoeres

scapularis). Due to protogynous nature, the sex-ratio tends to weigh more females. However, only a complete inclusion of individuals will give a realistic sex-ratio in labrids.

Maturity size appeared to be dependent on asymptotic length of the species in question. Smaller species matured at smaller size ranges and vice-versa. While most species matured synchronously, some had males or females maturing first. Fishes that had indeterminate sex were either juveniles or sub-adults. Females were generally dominant in most species.

Fecundity: Fecundity estimates exhibit a high variation perhaps due to diverse modes involved in spawning. Apart from pelagic eggs, fish lay demersal eggs with parental care, some are oral or body brooders and some are viviparous (Smith, 1982). Coral reef fishes are known to be highly fecund with annual egg production ranges from 10,000 to 10,00,000 per female (Sale, 1980a). In the present study, the overall fecundity range was 700 to 225850 eggs per female. Estimates probably varied due to size differences in the gonads, mature fish selected and the species.

Randall (1961) observed 40,000 mature eggs in a single female of Acanthurus triostegus, while in the present study a range of 10963 to 20400 was recorded. A. leucosternon had a relatively higher fecundity. Balistids lay demersal eggs (Barlow, 1981; Thresher, 1991) with some parental care. The low fecundity range of 936 to 7262 in Rhinecanthus aculeatus is possibly due to parental care exhibited by this species. The nature of eggs in Melichthys indicus is not certain as this species was frequently observed in the water column, and indicates a relatively higher

fecundity range (2056 to 9329). Fecundity estimate in some chaetodontid species like Chaetodon aculeatus was 2090, collected after gamete release; 2900 to 12900 in C. capistratus (Colin, 1989) and 10368 to 38400 in C. auriga from Lakshadweep (Vijay Anand, 1990 a). Fecundities of 1492 to 24532 (C. melannotus), 1060 to 2879 (C. octofasciatus), 1984 to 21975 (C. trifasciatus) and 2763 to 31065 (C. collare) were roughly comparable. Leis (1991) reported cirrhitids to have pelagic eggs but Paracirrhites forsteri showed a low fecundity (734 to 1894) and this could possibly be due to small gonads examined. Relatively high fecundities in Plectorhinchus orientalis, Myripritis murdjan and Neoniphon sammara possibly indicate pelagic spawning modes. Vijay Anand (1990 a) observed a fecundity of 4704 to 8743 in Halichoeres centiquadrus from Lakshadweep. H. scapularis had a relatively higher fecundity of 9992 to 15633. Low fecundity ranges in Thalassoma hardwicki and T. lunare may be due to high spawning frequency for which continuous output of mature eggs is required. Spawning occurred on a daily basis in Coris dorsomaculata, Thalassoma duperrey, and T. lucasanum (Tribble, 1982; Warner, 1982; Ross, 1985).

Gnathodentex aureolineatus had a high fecundity probably because it is a schooling and free swimming species. A similar reasoning perhaps holds good for Lutjanus gibbus and L. kasmira. Rangarajan (1971) reported a fecundity range of 42,100 to 3,32,620 in L. kasmira from Andaman Islands but in specimens from Lakshadweep this was low (33752 to 225850).

The reasons for a wide range in fecundity in Parupeneus bifasciatus (2968 to 146373) and low fecundities in P. barberinus and Mulloides flavolineatus are not known.

The three species of pomacentrids in general had low fecundities. Fecundity of Dascyllus trimaculatus (809 to 9634) was higher than estimates of 2125 to 7157 in D. aruanus (Pillai et al., 1987) and 1032 to 1993 in D. reticulatus (Vijay Anand, 1990 a) possibly because D. trimaculatus was observed to have relatively larger sizes. Fecundity depended upon the asymptotic length of the species which in other sense means an increase in age (e.g., lethrinids and lutjanids). An increase in fecundity with body size was also suggested by Robertson (1991) and with decreased egg volume was observed by Thresher (1982). Large species need to produce numerous eggs while small species that are confined to portions of the reef are unable to produce eggs for effective long range dispersal, lay demersal eggs with reduced fecundity and keep them out of plankton until they are well developed (Barlow, 1981). As coral reef fishes produce clutches of eggs on a daily, weekly, fortnightly, monthly and on a seasonal basis (Sale, 1991 a), fecundity estimates can be highly variable. However, from these estimates coral reef fishes studied in the present investigation tend to be highly fecund, capable of producing a large number of eggs annually. According to Murphy (1968), this selection for high fecundity, spread over time is to maximise the chances of the larvae to successfully return to a reef.

Spawning frequency: There is a great variety of patterns of spawning by reef fishes on the daily, lunar and seasonal time scales (Robertson, 1991). In the present study, the majority of species spawned continuously while two species, namely Acanthurus triostegus and Chaetodon melannotus spawned continuously but with short breaks. Nine species spawned intermittently and spawning was perhaps seasonal. Randall (1961) reported a lunar periodicity in the spawning of A. triostegus in Society Islands while Robertson (1983) observed a semi-lunar rhythm in eight acanthurid species from the Indo-Pacific. Observations on continuous spawning of A. leucosternon and A. triostegus (with breaks) perhaps supports previous observations.

Jeffery (1989) reported that butterflyfish eggs measured less than 1 mm in diameter and Vijay Anand (1990 a) observed a continuous spawning habit in Chaetodon auriga. In the present study, chaetodontid eggs measured between 0.74 to 0.93 mm and most of them were continuous spawners.

Spawning in certain pomacentrids takes place on a daily basis during the breeding season (Ochi, 1985) and continuous spawning in certain pomacentrid species from Lakshadweep was reported by Pillai et al. (1985), Madan Mohan et al. (1986) and Vijay Anand (1990 a). Maximum size of ripe ova in Dascyllus aruanus was 0.78 mm (Pillai et al., 1987) in Chromis caeruleus it was 0.35 to 0.45 mm (Madan Mohan et al., 1986) while in D. reticulatus it was 0.32 mm (Vijay Anand, 1990 a). All reports indicated the egg shape to be elliptical. Charles and Don (1966) found the time lapse between two following broods to be 7 to 14 days. The three

pomacentrid species in the present study had mature ova measuring between 0.74 and 0.86 mm along the longer axis and spawned continuously.

Mating in certain labrid species of the genus Thalassoma is a daily event during the reproductive season (Warner, 1982; Ross, 1985). Thalassoma hardwicki and T. lunare in the present study spawned intermittently; these distinctions are possibly seasonal peaks. In contrast, H. scapularis spawned continuously, and a similar habit was observed by Vijay Anand (1990 a) for H. centiguadrus from Lakshadweep. Among the two balistids, Melichthys indicus exhibited a discontinuous spawning while Rhinecanthus aculeatus spawned continuously. The holocentrid and mullid species also indicated a continuous spawning habit.

Cheilio inermis, Gnathodentex aureolineatus, Lutjanus gibbus, L. kasmira, Paracirrhites forsteri and Plectorhynchus orientalis indicated seasonality in spawning. Nzioka (1979) found spawning in 73 east African fish species to be continuous with some peaks. Rangarajan (1971) observed L. kasmira in Andamans to spawn only once a year but is likely to be spread over a period of 4 to 5 months. This also is perhaps true in individuals occurring in Lakshadweep. The maximum size of mature ova of L. kasmira in Lakshadweep (0.80 mm) appeared to be larger than in specimens from Andaman (0.65 mm). The intervals between each spawning appeared to be short in all intermittently spawning individuals.

From the present observations, it is evident that a high fecundity and a continuous spawning frequency are perhaps helpful to over come the uncertainities that larvae face before settling onto the reef.

Spawning seasons: Seasonal spawning patterns among the members of a single reef fish community may range from situations in which an entire location population spawns more or less synchronously once a year, through uni- and bimodal seasonal cycles that vary in their strength and timing, to appearently non-seasonal, year-round activity (Robertson, 1991). In the present study, majority of the species spawned continuously throughout the year with peaks in pre-monsoon and post-monsoon season. Relatively few species preferred the monsoon season. These aspects, to an extent have already been substantiated while discussing the spawning frequency. However, the exact timing of spawning in reef fishes can only be obtained by tracking the occurrence of mature individuals.

Among the two acanthurids, Acanthurus leucosternon had a protracted spawning period for about 8 months. Some ripe individuals seemed to occur in monsoon, but in general, monsoon months are perhaps avoided. The short breaks in spawning in A. triostegus were evident in the ova diameter polygons and the occurrence of spawning fish in three distinct time scales confirms the fact that it is a continuous spawner but with breaks.

The three species of chaetodontids from Gulf of Mannar namely, Chaetodon collare, C. melannotus and C. octofasciatus seem to be affected by both the south-west and north-west monsoons and mature fish were either absent or occurred in low proportions in June, July, November and December while mature individuals of C. trifasciatus did not occur in June and July in Lakshadweep indicating a low reproductive output during monsoon. Therefore, variation in seasonal environmental conditions seem to locally alter spawning patterns. On an annual basis, Cheilio inermis had

two extended spawning peaks which coincided with pre-monsoon and post-monsoon seasons, which are supported by the ova diameter polygons indicating intermittent spawning. A similar reasoning holds good for other intermittent spawners like Lutjanus gibbus, L. kasmira, Paracirrhites forsteri and Plectorhinchus orientalis.

Among the labrids, spawning in Halichoeres scapularis seemed to be uninterrupted by environmental conditions. A similar pattern was also observed in Pomacentrus pavo. While Thalassoma hardwicki and T. lunare characteristically avoided monsoon season, Melichthys indicus spawned just before and after monsoon. Rhinecanthus aculeatus appeared to have an extended spawning season. The mullids, holocentrids and pomacentrids also spawned continuously but with breaks during monsoon. A peak spawning season during september to December and February to March was evident in Abudefduf glaucus from Minicoy atoll (Pillai and Madan Mohan, 1990).

The characteristic avoidance of monsoon seasons by spawning individuals in Lakshadweep is perhaps to tide over the unfavourable rough weather which would transport eggs and larvae in unfavourable direction. Unusually bad weather may interfere with the seasonal timing of spawning of certain reef fish (Johannes, 1980). A dual monsoon effect observed in the Gulf of Mannar further supports the fact that environmental conditions can influence spawning season. Robertson (1990) stated that rough physical conditions evidently are stressful for adults and depress their reproductive output. The shallowest parts of the reef comprise a stressful environment in which to live (Sheppard et al., 1992) and this could perhaps not only affect spawning fishes but also cause mortality of fish larvae. Walsh

(1987) suggested that spawning output could be tracking seasonal change in the suitability of benthic environment (due to changes in food availability, temperature and physical stress) for the growth and survival of juvenile fishes after they arrive in a reef. As monsoons are regular phenomena in Lakshadweep and Gulf of Mannar regions, coral reef fishes inhabiting these regions might be adapted to spawn during favourable seasons. Continuous spawning is perhaps a regular phenomena during the spawning seasons. This is also supported by the continuous occurrence of juveniles during the pre-monsoon and post-monsoon seasons.

Occurrence of juveniles on seagrass beds.

Bell and Pollard (1989) identified many major characteristis of fish assemblages associated with seagrasses, among which the importance of this habitat in harbouring newly settled fish and juveniles was discussed. Juvenile association with seagrass beds was one aspect among 19 groups of fauna and flora identified by Den Hartog (1979). Where coral reefs occur in conjunction with seagrass beds many recruits of a number of species will spend the first portion of their post-larval life in the seagrass beds and invade coral reefs at a later age when they are capable of evading predation (Shulman 1985 a).

In the present study, 28 reef fish families were represented by new recruits or juveniles on seagrass beds on Kavaratti atoll. Of these 28 families, juveniles belonging to Acanthuridae and Labridae were most dominant. Victor (1987) observed labrid larvae to have long larval lives and larvae of different ages occurred within the same water mass and young

cohorts of larvae appeared continuously over the sampling period. The extended larval lives perhaps included labrids in almost all samples in Lakshadweep. Schooling species showed dumped, highly variable recruitment that presumably resulted from aggregative settlement (Shulman, 1985 b) and this can be related to the high occurrence of juveniles of Acanthuridae, Carangidae, Holocentridae, Mullidae, Scardiae and Siganidae all of whose adults exhibited schooling behaviour. The observation of Shulman (1985 b) on non-schooling species that showed random, less variable recruitment patterns could be probably applied to those families in the present study that were relatively low in representation. Apart from the reason mentioned, lower junenile counts in certain families (Balistidae, Platacidae, Haemulidae, Kuhlidae, Mugilidae, Pemphridae, Pomacanthidae, Pomacentridae, Scorpaenidae and Sphyraenidae) is possibly due to the choice of habitat at settlement. The importance of shelter or reef topography for fishes after recruitment has been emphasised by Shulman (1985 a).

Seagrass beds were found to be unsuitable for highly habitat-specific fishes like pomacentrids. The reasons for this are not known. However, Sweatman (1985) found a greater larval recruitment in certain pomacentrids among coral heads where adults resided, than to corals with other congeners or vacant controls. Species that exhibit higher recruitment on seagrass beds are a distinct subset of diurnally active fish that inhabit the back reef habitat (Shulman, 1985 a). In the present study, this was reflected with dominant occurrence of juveniles of Acanthuridae, Labridae, Carangidae, Mullidae, Scaridae and Siganidae.

These herbivorous and benthic invertebrate feeders perhaps find abundant food among seagrasses. The two advantages that seagrasses offered new recruits are shelter and food during their early life history stages when individuals are susceptible to predation (Bell and Pollard, 1989). Shulman (1984) stated that availability of refuges from predation was an important factor determining population sizes rather than availability of food.

In the present study, it was observed that adjacent bare sand flats were almost devoid of juveniles while they were abundant on seagrass beds. This indicated their preference for shelter. Various size ranges recorded for each group suggested that certain families remain on seagrass beds for a relatively longer duration of time and are represented by post-larvae, advanced post-larvae and juveniles, while they were abundant on seagrass beds. This indicated their preference for shelter. No apparent order seems to be imposed on the variety of settlement sizes (Victor, 1991). This long-duration association could mainly be due to abundant food resources available for juveniles. Weinstein and Heck (1979) emphasisd the great invertebrate biomass on seagrass beds while Den Hartog (1979) grouped various fauna and flora on sea grass beds of which certain invertebrate groups from important fish food. From his description, there appears to be a wide selection of food items for diverse feeding modes for various size groups.

Juvenile settlement of dominant families on seagrass beds was generally observed to be continuous. Victor (1991) found that species of fish larvae appear somewhat regularly, in random or periodic short cycles; a few species tend to settle in large numbers on rare occassions.

Acanthurid juveniles steadily occurred on seagrass beds with peak settlements during pre-monsoon and post-monsoon months. Randall (1961) found maximum recruitment of Acanthurus triostegus in mid January and June to mid November in Moorea, French Polynesia. Juveniles and sub-adults of chaetodontids were generally more abundant in shallow areas whether it be coral reefs or seagrass beds (Fricke, 1973). Though juvenile chaetodontids were not very abundant on seagrass beds they occurred consistently round the year. A similar trend was seen in the case of Holocentridae. Occurrence of juveniles of Apogonidae, Lutjanidae and Mullidae was moderately seasonal while caragnids and siganids exhibited a remarkable seasonality. Labrids clearly indicated summer peaks in settlement.

Juveniles in most reef fish families in Lakshadweep appeared less abundant during monsoon months, possibly because of avoidance of this season by adult spawners. However, some juveniles observed during monsoon seasons could result from the pre-monsoon spawning. The continuous occurrence of juveniles in a variety of size ranges confirms the continuous spawning habit in most species examined.

Seagrass beds as fish nurseries: In most seagrass habitats many of the abundant seasonal residents are individuals that settle from the plankton (Bell and Pollard, 1989). The absence of seagrass or algal zones was found to supress recruitment (Shulman, 1985 a). Many reef fishes treat reefs and seagrass beds as a single habitat and seagrasses contain juveniles of several species that occur in the adult fauna in the neighbouring reefs (Ogden and Zieman, 1977). A similar system was observed on seagrass beds

of Kavaratti atoll. The 'nursery phase' discribed on seagrass beds mainly concerns the role of the habitat as a fish nursery, where a small food web is set up. The food and shelter components are mainly taken care of. After transition, sub-adults migrate to adjascent habitats Juveniles settling on seagrass beds remain there only for a short period of time (days to weeks) and migrate to nearby reefs as they got older (Shulman, 1985 a; Shulman and Ogden, 1987). Seagrass beds also support fishes that are dependent on seagrasses directly for food or indirectly by preying on seagrass invertebrate inhabitants.

Monthly juvenile abundance and effects of environmental parameters

Juvenile abundance was generally high during pre-monsoon and post-monsoon seasons. As discussed earlier, the low spawning output and juvenile occurrence during monsoon is perhaps due to unfavourable environmental conditions. Summer peaks in recruitment are possibly related to temperature. Seasonal differences in larval fish assemblages were observed in the Great Barrier Reef (Shulman, 1985 b; Leis and Goldman, 1987). Summer peaks in larval recruitment were reported by Williams and Sale (1981) and Williams et al. (1984) while Middleton et al. (1984) stated that recruitment of temporary residents was the main cause of seasonal variation. Apart from these reasons that contribute to variations in larval abundance on seagrass beds, timing of adult spawning, timing of settlement, total number settling at a given time and shifting to adult habitats also influence the numerical data. Robertson et al. (1988) discussed that timing and magnitude of settlement are influenced by production and planktonic processes of fish larvae. The arrival, mortality and emigration of

seasonal residents influence total abundance of larval fish (Bell and Pollard, 1989). The causes responsible for variation perhaps determine the larval fish variability through time.

In the present study, the abundance of larvae on seagrass beds was not affected by temperature while on the other hand, increased salinity was coupled with increased juvenile occurrence. Conventionally, salinity increases with temperature and highest temperatures were recorded in the pre-monsoon period (summer months). Though these two parameters are related, a distinction made by juveniles suggests that neither of the two parameters influenced their abundance but are perhaps dependent on other factors like monsoon seasons, currents and tides. Vijay Anand (1990 a) and Suresh (1991) found variations in water temperatures and salinity on Kavaratti atoll to be low. In general, fluctuations in environmental parameters were only slight perhaps due to their oceanic conditions. The south-west monsoon divided the annual seasonality into the three broad seasons, namely pre-monsoon, monsoon and post-monsoon. The coincidence of juvenile abundance during premonsoon and post-monsoon seasons (which show relatively higher temperature and salinity regimes compared to monsoon) may possibly be related to higher salinities. Johannes (1978) stated that over much of the tropics, two monsoon-related seasons replace the four solar seasons, but are characterised more by changes in patterns of wind, rain and currents than temperature and day length.

Lunar cycles in the return of juveniles to adult habitat at the end of the planktonic phase occurs in many species (Johannes, 1978; Thresher,

1984; Robertson et al., 1990). Occurrence of more juveniles during the new moon phases (dark nights) is perhaps advantageous for settlers to combat predation. Lower settlement rates during weeks around the full moon (brighter nights) was reported by Robertson et al. (1988). In the present study, this adaptive significance could have increased the number of post-larvae settling on seagrass beds during the new moon phase.

To sum up, seagrasses at Lakshadweep have emerged as dynamic sub-habitats with one of their important functions as nurseries for a wide variety of reef fish. These zones steadily supplied juveniles and sub-adults to other adult habitats. Apart from providing shelter and food for juveniles, these zones formed feeding grounds for adult fishes; seagrasses themselves being fed upon. Juveniles of certain families characteristically used seagrass beds as nurseries while others perhaps had different specific habitat requirements. Environmental parameters had little influence on their abundance while the phenomenal monsoon seemed to affect their abundance either directly or indirectly by providing unfavourable or favourable environmental conditions for settlement. Recruitment onto seagrass beds was highly seasonal in some families but most families showed continuous recruitment.

CHAPTER - VI

FISHING METHODS FOR INDIAN CORAL REEF FISHES

FISHING METHODS FOR INDIAN CORAL REEF FISHES

INTRODUCTION

Fishing is no doubt the most important exploitative activity on coral reefs (Russ, 1991). The fisheries potential of coral reef areas, worldwide is estimated at 6 million metric tonnes per year which represents about 7% of current world marine capture fisheries (Smith, 1978). Coral reef fishes on a worldwide basis are underexploited (Munro, 1984). The two oceanic island ecosystems and the continental reefs of India provide a vast area for commercial exploitation, but fishery resources are underexploited. In Lakshadweep, the latest annual landing figure in 1992 stands at 25,404 tons (Source: Director of Fisheries, Lakshadweep) as against an estimated potential of 90,000 tonnes of the Laccadive sea (Jones and Banerji, 1973). The marine fish landings in the Andaman and Nicobar Islands has been estimated at 22339 tonnes in 1991 (Santhana Krishnan, 1993). Reports of fish production from continental reef systems for specific areas are not available separately.

Despite high potential of fish yields from coral reefs in India, exploitation is relatively of a lower magnitude due to constraints in operation of various gears on complex topography and lower fishing efforts in these regions. Reef fish in general are sedentary and habitat specific, therefore they require special gear and methods for exploitation or behavioural situations should be made use of to effeiciently capture them. Before introduction of modern fishing methods, coral reef fishery was mainly based on traditional methods.

During the course of the present investigation, observations have been made on various fishing methods employed for fishes other than tuna pole-and-line method. Fish collections for biological studies in the present investigation were obtained by operating such gears and were also supplimented by operations by fishermen. A wide variety of traditional and modern fishing methods existing in Lakshadweep, Andaman Islands and the Gulf of Mannar region are described.

REVIEW OF LITERATURE

The earliest descriptions of fishing methods of Lakshadweep have been given by Hornell (1910), Ayyangar (1922) and Burton (1940). Subsequently, Jones (1958) gave detailed accounts of various gear, their specifications and operational procedures for the capture of tuna-live-bait. Brief accounts of seine nets, gill nets, harpoons, traps and fire torch fishing were described by Balan (1958). In describing the fishing industry of Minicoy, Jones and Kumaran (1959) made observations on various off-

season fishing methods like seine nets with different operational procedures, drive-in-nets, cast nets, hooks and lines and harpoons. Further, Jones and Kumaran (1980) stated that without much organised efforts, fishes other than tuna form about one fourth of the landings in Lakshadweep, James et al., (1986) mentioned that traditional methods cannot effeciently harvest this resource but diversified efforts like drift/ gill-netting could enhance fish production greatly. Kumaran and Gopakumar (1986) found that increase in the landings of fishes other than tuna, consequent to the introduction of mechanised boats is of a lesser magnitude. An apprisal of the marine fisheries in the island territories of Lakshadweep and Andaman and Nicobar Islands has been made by Alagaraja (1987). Indegeneous fishing methods of Kalpeni Island, Lakshadweep were described by Vijay Anand (1990 b).

Gear-wise annual average fish production in the Andaman and Nicobar Islands indicated that the major portion of the catch comes from hook-and-line operations (Marichamy, 1974). Fisheries occupies a comparatively low place in the economic complex of Andaman and Nocobar Islands and gill nets, boats seines, shore seines, cast nets and hooks and lines are common gears (Kumaran, 1973). Eleven different popularly used fishing methods from the region were described by Sen (1973). The performance of bottom trawling has been studied by Sudarshan (1977). The fisheries activities of these islands have been summed up by Arif (1983) while a brief account of light fishing has been given by Lakshminarayana (1986).

Fish catching techniques must be adapted to their biotope (Hignette, 1979). Various advantages and disadvantages of methods of fish capture were discussed by Solomon and Hawkins (1981). Due to uneven underwater reef topography, fishing techniques are usually restricted to the use of traps and vertical hooks and lines in the Caribbean sea (Munro, 1983). Yields of fish traps located in the boat channel of Tikehau atoll have been analysed by Morize (1984) while artisinal fishing from the same region is the main resource deriving operation (Blanchet, 1985). Dazell and Lewis (1989) reviewed the South Pacific tuna bait-fisheries where they described the operation of stick-held dip nets.

MATERIAL AND METHODS

Descriptions of various fishing methods of Lakshadweep are given based on direct observations, participation by the investigator and at times operation by the investigator. The methods mainly consist of traditional operations but a few modern methods have also been successfully introduced and are being practiced. Observations on methods practical in Andaman Islands and on the reef regions of Gulf of Mannar are also briefly described. Based on the type of gears operated, the methods have been classified into broad groups, namely, covering gear, drive-in-gear, encircling gear, falling nets, fishing without gear, light fishing, lifting gear, line fishing, seine nets, traps and wounding gear.

OBSERVATIONS

A. FISHING METHODS OF LAKSHADWEEP

1. Covering gear: The gear is called Kallumoodal and is operated by a single person. A conical net resembling a cast net with lead weights beneath is used to cover small coral boulders that are partly exposed during low tides. The boulder is then shaken thoroughly to scare out all hiding fish into the net. This method makes use of the hiding habits of fishes. Commonly caught species are a variety of seeranids and a few acanthurids (Cephalopholis argus, Epinephelus hexagonatus and Acanthurus triostegus).

A varied version of 'Kallumoodal' involves a similar technique but is operated on large, submerged ramose, massive/dead corals. This method makes use of a brown or red coloured fine meshed net that is spread on the desired substratum around midnight by two or more fishermen and is hauled up just before it is dawn. The principle used to catch fish is their nocturnal behaviour. Nocturnal fish leave their day-time refuges soon after it is dark to feed on zooplankton in the water column. The nets are placed around midnight after they leave their homes. When these fish try to get back to their day-time refuges before dawn, they are captured. Commonly caught fishes are apogonids (used as tuna bait), holocentrids and pemphrids.

2. Drive-in gear: These gear are used in three indigenous methods of fishing and are based on the habits of fishes, tides and seasons.

a. Chaal: This involves construction of pathways on the reef crest by piling dead coral boulders. These paths have wider openings towards the seaward side and taper into a narrow channel on the lagoon side where a bag net is placed. The opening of the bag net varies in size between 0.50 and 1.50 m and tapers to about 20 cm at the distal end. The mouth of this net is fitted to the channel using wooden sticks; provision is made for a single person to sit and wait for fish to enter. The fish are normally chased using a stick to beat the water or are caught when trying to enter the lagoon from the adjacent reef flat and reef slope areas. Entry of some schooling fishes like mullids, polynemids and scarids result in heavy catches. Chaal is operated both during day and night. Entry of fish is normally judged by visibility during day while a string diagonally passing through the net acts as a feeler line when operated at night. All small fishes trying to enter the lagoon compose the catch.

b. Padhi: This is similar to Chaal but the open end faces the lagoon and the opposite end is normally closed. Unlike Chaal, the construction does not involve width variations but resembles more or less like a shallow pond. Fish that try to leave the lagoon with a receeding tide normally enter and remain in the enclosure and at times are also chased. Once fish enter Padhi the mouth is closed, the fish are caught using nets or harpoons. Padhi is operated both during day and night but in the latter case, fish are removed after dawn. Both Chaal and Padhi are family owned properties that are acquired by inheritance.

c. Kandalivalai: This gear includes a scare line and three types of nets. The nets are operated in the lagoon at places where corals do not form obstacles, and are positioned parallel to the reef crest. The scare line made of dried coconut leaves, is laid opposite to the Kandalivalai in a semi-circular fashon. Unlike the nets, the scare line (300-600 m) is laid over ramose/massive coral substratum from where greater amount of fish can be scared into open lagoon areas.

The Kandalivalai has the following specifications: Length 21 to 35 m, height 2 to 3 m, number of floats-30 to 50 nos, weight coral stones or lead, mesh size 6 cm, netting material No.8 polyamide, sinker rope No. 16 or No. 17 nylon, head rope No.12 nylon, number of persons operating 4 to 6.

The distance between the scare line and the net ranges between 500 and 700 m. The operation involves dragging of the net and scare line towards each other, the former at a slower pace and the latter at a faster pace. Scare lines are pulled into the two boats positioned at opposite ends. Two more nets, namely, the Fathivalai and Manakathavalai are operated behind the scare line and Kandalivalai respectively, to capture smaller escaping fish.

Fathivalai has the following specifications: Length 20 to 25 m, height 2 to 3 m, mesh 5.5 cm, netting material No.5 polyamide, number of floats 20, sinkers - coral stones, number of persons operating 4. The 'Manakathavalai' has the following specifications:

Length 10 to 20 m, height 2 to 3 m, mesh 3 cm, netting material No.2 polyamide, number of floats 10, sinkers - coral stones, number of persons operating 3.

This method catches a wide variety of fishes both large and small, inhabiting the lagoons. Some of the common groups include acanthurids, balistids, carangids, hemiramphids, lethrinids, lutjanids, mullids and siganids.

3. Encircling gear: Operation of these nets involves various procedures employing the same principle. A desired fish aggregation is spotted and a net is payed around them. Nets are either pursed by individual fishermen in deeper waters or the fish are gilled without pursing in shallow waters. This method is commonly used to capture bait fish for tuna. Operations are either large scale involving mechanised boats and scare lines or are small scale operations with or without country crafts. Encircling is also done around massive coral zones encompassing fishes associated around the habitat. A single person enters the enclosed region and scares the fish using coconut leaves, (trimmed into a brush fashion). Fish are normally gilled or entangled.

Encircling nets do not have fixed specifications. Normally, bait fishing nets are small meshed (less than 0.5 cm) while others range from 1 to 3 cm. The head rope is fixed with floats and the foot rope with lead sinkers. The lengths range from 10 to 15 m and the height is normally 2 to 3 m. Four to six persons operate such nets. The polyamide material

used earlier has been recently replaced by monofilament so that nets are not easily visible to fish even in clear waters of coral reefs.

Kudakavalai is a type of encircling gear (can also be termed as boat seine) made of monofilament and ranges in length between 50 and 70 m. Operation is normally conducted in the outer sea by 6 or 8 fishermen and two boats powered by outboard engines. This method is seasonal and is conducted one month before monsoon to capture spawning aggregation of halfbeaks (Hemiramphidae). Nets are payed around fish schools in a circular fashion and fish are gilled. Mesh size was observed to suit the fish head depth of 2.5 to 3 cm.

4. Entangling gear: Usage of this gear involves two methods where fish are normally caught by gilling in either passive or active gear.

a. Arigalavalai: This gear captures long beaked fish (Belonidae or Hemiramphidae). When a school is spotted, the net is operated in the lagoon by dragging it from the centre towards the reef flat in a perpendicular manner. The net has the following specifications: length 8 to 15 m, height 2 to 3 m, mesh 3 cm, netting material No.5 polyamide or monofilament, number of floats 30 to 40, sinkers - coral stones, number of persons for operation 10 to 12. The beaks of the fish get entangled or they are at times gilled. This method is used only in the monsoon season perhaps when fish enter the lagoon to breed.

b. Fathivalai: Set gill nets are normally operated by two persons and a country craft in the lagoon at dusk time. Nets are payed parallel to the shore or reef margin. Fish are normally gilled and hauled up at 10.00 pm. The net is again set at 3.00 am and finally hauled up at 8.00 am. Specifications of gill nets vary greatly: length 10 to 90 m, height 2 to 4 m, mesh 3 to 15 cm, netting material No.2 to 8, polyamide/cotton/nylon, number of floats 25 to 30, sinkers - lead or coral stones, number of persons to operate 2 to 8. Fish catch composes of acanthurids, belonids, balistids, caesionids, carangids, elasmobranchs, holocentrids, lethrinids, lutjanids, scarids, etc. of varying sizes.

Set gill nets are also operated outside the lagoon on reef flats or reef slopes (3 to 6 m water depth) during calm weather and are made up of stronger material. A typical gill net outside the reef is called Halakvalai. The net is either payed parallel to the reef crest or in a perpendicular fashion at dusk. Fish are emptied out of the net around 12.00 midnight. The remaining catch along with other fresh catch is hauled up with the net at dawn. Eight persons are normally required to operate this net. Drift gill nets are less popular but if they are used, a constant watch is kept and they are hauled up before reaching the reef.

5. Falling nets: These nets are thrown on fish aggregations in shallow waters.

a. Veechuvalai: This is a common, well known cast net that is used to catch fish along the shore in the lagoon or on the shallow parts of the reef flat at lowtides. Small perches, acanthurids, belonids, carangids, hemiramphids, kuhlids, labrids, lethrinids, lutjanids, mullids, polynemids and scarids are commonly caught.

b. Idupumanakam: This method is employed to catch only mullids (goat fishes) during the fair season. A number of fishermen (upto 50) stand in a row on the shallow reef flat with their cast nets and wait for passing schools of goat fishes. When the first person spots a moving school he throws his net and is subsequently followed by others. By the time the school passes the last fisherman, the school is almost fully fished. On enquiry, the fishermen say that these schools were spotted only on days with dates of even numbers.

6. Fishing without gear: This method involves the use of hands or substances that narcotize fish in water.

a. Shark fishing by hand: This is not an organised fishing practice but is used to catch sharks measuring 0.5 to 3 m long. Schools of tuna and sharks were observed to be associated with floatsams. Fishermen first catch tuna using the pole-and-line with or without live bailt. Once tuna is fished, they cut few pieces of tuna and trail their blood alongside the boats. Sharks are attracted by the smell of blood and surface up near the boats and swim around with their dorsal fins above water. The fishermen take hold of the

dorsal fins to lift them out of water and into the boat. Only experienced and elderly fishermen ventured on such methods. One particular fishing unit returned with 500 tunas and 90 sharks, the latter fished out by hands.

b. Fish poisoning: A poisonous dried fruit, called Nengi is obtained from mainland. This is mashed into a paste along with fiddler crabs caught from the beach and rolled into small balls (1 to 2 cm diameter). This is thrown into the water where fish are spotted. Fish that consume this mixture react by jumping out of water and fall back to die. Fishermen skin dive and remove the fish from water, cut them open immediately and remove the entrails in order to make it safe for human consumption.

7. Light fishing: This method involves the use of lights at night either to attract fish or stun them and make them vulnerable to capture.

a. Paravaichaadal: This is a seasonal fishing method practiced before onset of monsoon for flyingfish. 6 to 9 persons on one to four country crafts or mechanised boats set off for fishing after it is dark. Fishing is performed outside the reef using fire torches made up of dried coconut leaves and old rubber tyres. The torches are lit and held by one or two fishermen with their left hands and a wounding gear (Chilla) in their right hands, while others manouver the boat when flyingfish get attracted to the light and surface up, they are harpooned using the Chilla.

b. Meenukoothal: This method is practiced at night using fire torches and two or three - pronged harpoons. Fishermen wade in the shallow waters of the lagoons usually during low tides using fire torches. Fish present in the area are stunned by light and stay motionless when they are harpooned.

c. Night light fishing: Adopting the principle of stunning fish with light, the present study made some modifications to collect large samples of fish at night. A bright torch light was used to stun fish hiding in their nocturnal shelter among coral boulders on shallow regions. A minimum of three people, one for overturning or moving dead coral boulders, one for focusing the light and one for capturing the fish are required. Fish became numb and stayed motionless, facilitating effortless capture. Commonly caught fish include acanthurids, apogonids, chaetodontids, epinephelids, plesiopids, pomacentrids etc.

8. Lifting gear: These are nets of variable sizes and are operated in the lagoons or in the outer sea with boats, adjacent to the reefs to catch small fish.

a. Chaalai valai: This gear involves a large net of a mesh size below 0.5 or 1.0 cm, made of No.2 polyamide. Two ends of the net are secured to two bamboo poles that are placed across the boat and held by two fishermen. The other two ends are tied to relatively longer bamboo poles that are held close to the boat by two fishermen. Once a small school of fish is spotted, a scare line is

payed all around to enclose them. The line is slowly pulled into the boat to concentrate all fish into a limited area. When they are brought close to the boat, the longer poles are extended away from the boat in such a manner that the net is spread beneath the fish aggregation and is subsequently lifted along with the fish. This method is usually used to capture live bait for tuna.

b. Vhotundha valai: This is a rectangular or squarish net with fine mesh, two ends are fastened a little above the water level to two firmly fixed stakes. The net is in a slant position, with its other end weighted by coral stones and attached to strings. Fish are chased towards the net by 4 to 6 fishermen from adjacent areas either by draging a scare line or beating the water. Once fish move onto the net, the free ends are lifted by the ropes and fish are removed. Commonly caught fish are labrids, mullids and a variety of tuna bait fish.

9. Line fishing: This method involves the use of monofilament nylon twine and hooks under various procedures to capture fish.

a. Trolling: This method has been introduced by the Department of Fisheries, Lakshadweep and has become increasingly popular with the introduction of mechanised craft and outboard engines for the local country craft. Troll lines measuring 30 to 40 m long are operated in the open sea. Usually four troll lines, two from each side of the boat are used. The rigging support is given by bamboo poles or the transom frame of the mechanised boat, while

oars are used in the country boats. The ideal time was observed to be during the onset of low/high tides when the fish surface up. Barbed hooks of varying size (No.2,3,4 and 6) on a monofilament nylon twine of No.100 are used. Troll lines may or may not have baited hooks. Unbaited hooks have a lead weight to which are fastened coloured plastic filaments. The colour of the filament varied with the colour of the bait available in the particular season. When troll lines are intended to be baited, belly flanks of already captured fish or freshly caught flyingfish using smaller version of troll lines and tender coconut as bait are used. Commonly caught fishes include tunas, seerfish, dolphinfish, carangids, perches and gars.

b. Hand lines: Simple hook and lines using monofilament twine and bait are operated both during day and night either from the beach, boats or the reef crests. Sizes of hooks, lengths and strength of monofilament twines, sinkers and bait used are highly variable. Various baits used are small fish, belly flanks and stomach of tuna, octopus, squid, sipunculids, hermit crabs, fiddler crabs, seaweed and wheat flour. A special method called Karainool is operated for large perches on the leeward size of the island. Entire fish (usually labrids) are used as baits and hurled far from the land. Ends of the line are tied to firm supports. Catch is normally checked after an hour.

c. Longlines: Set long lines and drift long lines are operated using nylon ropes of No.12 or 15 as the main line and No.10 for snood

lines. The main line ranges in length from 100 to 500 m with snoods at an interval of every 10 or 15 m. As limitations of craft exist, only desirable lengths of long lines are operated. Hooks of sizes No.2 to 4 are used with either tuna head or turtle meat as bait. Lines are operated both during day (early hours) and night. Large buoys with marker flags are used at either ends and in between to denote the orientation of the line. Set long lines have an anchor at one end and are usually set by fishermen on their way to fishing while drift long lines are accompanied by boats. Sharks, seerfish and tuna are caught by this method.

10. Siene nets:

a. Shore seines: These vary greatly in dimensions and in materials used. Nets are operated parallel to the shore either by two people or by boats with 10 people. Depending on the size of the nets, they are payed in deeper waters and are dragged onto the shore or the reef crest. Small nets measure about 10 to 12 m while larger ones may be 50-70 m long. Catch composition is similar to that of Kandalivalai.

b. Chaalai fishing by women: Chaalai is a term referred to small fish and also to bait fish. This method is practiced by women during low tides. 3 to 4 women drag a velon screen on the lagoon bottom after spoting small fish while other women spread themselves out covering a large area and come towards the net, beating water and scaring fish into the net. Juveniles and sub-adults inhabiting the sand flats and seagrass beds are caught.

11. Traps: Locally manufactured traps are placed with or without bait in desirable places on the reef for varying lengths of time.

a. Koodu: This is a locally made triangular fish trap that is 1.5 m long 1 m wide at the base and 0.5 m in height; made from locally available reeds and shrubs. At the centre of the base, there is an entrance leading into the trap in a zig-zag manner. The trap is transported on a raft or country craft to a desirable place in the lagoon. It is lowered into water in a perpendicular orientation with the shore and weighed with coral stones. Fish that are trapped are emptied out through a separate opening, at regular intervals. Traps are operated during all seasons. Labrids, lutjanids, mullids and serranids are usually caught.

b. Moorothakoodu: Usage of this trap is extinct but details were collected from an elderly fisherman. The specifications of the trap are as follows: length 5 to 8 m, width 3 to 5 m, height 4 m, shape rectangular, removable door 1 x 1 m, material coconut wood. The trap was fabricated on the island and transported to the reef flat region on one or two boats. The position on the reef flat is chosen in such a manner that about 2 feet of the trap is exposed during low tides. The trap has an entrance on the longer side and is kept in position with large coral boulders as weight. A gap of 12 to 15 days is allowed after installation for seasoning the fresh wood and subsequent tightening of joints. Operation of unseasoned traps were believed to produce creeking sound that scare away fish. Once ready for operation, fishermen hang turtle meat as bait

that attracts sharks. The catch is checked periodically during low tides. As large fish and sharks are caught, they are first harpooned and killed through the door and removed. These are usually permanent structures underwater.

12. Wounding gear: Harpoons involving different operational procedures were used earlier but their use is slowly dwindling now.

a. Chilla: This is a traditional harpoon that is composed of two parts, namely, the wounding part and the handle. The wounding part consists of 12 sharp spikes, 6 in the inner whorl and 6 in the outer whorl. They are supported by interwoven cotton twine. The tips of the spikes are covered with lead sheaths to enhance the sharpening effect. The 12 spikes in a frayed manner, increase the effective wounding surface area. As this part is expected to be rigid and have a certain degree of flexibility, it is made up of arecanut wood. This is secured to the handle that is 2 m long, made up of coconut wood. This harpoon is normally operated during dusk time by a fisherman who stands in knee-deep water and waits for surface swimming fishes. The presence of a fish is identified only by the ripples it causes. The harpoon is aimed at the head of the ripples to capture the fish. Chilla is also used during day time from boats or for light fishing for flying fishes.

b. Kooduli: This is a three pronged harpoon used specially for seerfish. Two spikes on the outersides have a barb while the one in the centre is smooth. The opposite end of the wounding part

has a nozzle into which a handle can be fixed. The nozzle is tied with a plaited nylon rope that is drawn into a loop to which a retreiving line of 100 to 500 m is attached. The rope and the handle are held together by fishermen. The operational procedure involves 2 to 3 persons who cross the reef into the outer sea. While one person manouvers the boat the other lures seerfish to the surface using a painted wooden model of a flyingfish attached to a pole and line. When the fish surfaces it is harpooned, the handle is pulled back and the fish is slowly retrieved with the line.

c. Ottauli: This is a simple wounding gear with a single spike and a reverse barb and is attached to a wooden handle made up of coconut wood. The arrangement of a retreiving line is the same as in Kooduli. This is carried in all types of boats and is used to overpower large sharks or tuna when caught on long lines or troll lines.

d. Koku: This is a type of lifting device which has an upturned, strong metal part attached to a wooden handle of varying length. This is mainly used to lift large sharks or tuna on board the vessel after having been caught on troll or long lines.

B. FISHING METHODS OF THE ANDAMAN ISLANDS

1. Covering gear: This is a conical basket made of locally available reeds. The wider part of the cone is about 0.5 m wide while the narrower part has an opening through which an entire arm can be passed

in. The height of the basket corresponds to an arms length to facilitate removal of trapped fish. When the fish are spotted in shallow waters, the basket is plunged onto them and the catch is emptied using hands or spears. A variety of perches are caught.

2. Entangling gear: Gill nets are popularly used. They are operated between channel reefs or 10 to 15 km away from the shore in open sea, and are normally payed perpendicular to the shore. Sizes, material and mesh sizes vary greatly with each unit. Mesh sizes ranging from 3 to 20 cm are used depending on the size of fish to be caught. Gill nets are either set or are drifting type and are operated by 4 to 6 fishermen using country crafts.

3. Falling nets: These are cast nets of varying mesh sizes (1 to 3 cm) with peripheral strings and pockets. Lead weights are used on the open end. Shallow reef areas without excessive coral outcrops are selected for operation to avoid damage to the nets. Small to medium sized fish are caught.

4. Fishing without gear: This involves usage of an intoxicant obtained from locally grown wild fruit. The pulp is obtained by grinding with pieces of solid stone. Barriers on a selected area are errected using palm leaves, rocks or coral boulders so that fish does not escape. At the onset of low tides, the pulp is mixed with water to intoxicate fish and facilitate easy capture by hands.

5. Light fishing: This method is similar to the one practiced at Lakshadweep (Meenukoothal). Coconut leaves as fire torches and single-pronged harpoons are used to stun fish in shallow waters during night. This is a group activity involving men, women and children.

6. Line fishing: Usage of hooks and lines is very popular to catch various carnivorous reef fishes, especially lethrinids, lutjanids and serranids from shallow to deep areas.

a. Handlines: Simple hand lines using hooks (Nos. 4 to 10) are commonly used in combination with monofilament nylon twine. These are operated at all times of the day either from the shore or from country crafts. Fish is normally used as bait.

b. Troll lines: 5 to 10 lines operated from each country boat powered with an engine. The monofilament twine is thicker (Nos. 90 to 120) and hooks commonly used are Nos. 2, 3, 4, 6 and 10. Cloth bits of varying colours are used as lures around the hook. Commonly caught fish are belonids, carangids, seer fish, sharks and tuna.

c. Longlines: These units consist of a nylon head rope and snood lines with large hooks at intervals of 10 m. Each longline 'basket' is about 50 m long containing 5 hooks. Many such basket units are carried and are attached to each other to form desired lengths. These are small long-line units and do not exceed 500 m in length and are operated during nights.

7. Seine nets: The sein net measures 15 to 40 m with a head rope fixed with floats and foot rope with sinkers. One end of the net is fixed on the shore by a fishermen, while the net is carried in a boat, payed in a semicircular manner in the sea and the other end subsequently brought to shore. 10 to 15 fishermen pull the net onto the shore while some fishermen swim slowly with the net to ensure its position. Fish are gradually concentrated before they are removed near the shore. Operations are normally carried out during day, in bays, with extensive sand flats.

8. Wounding gear: Two types of wounding gear mentioned below are commonly seen in Andaman Islands. They are normally operated in shallow clear waters on coral reefs.

a. Bow and arrow: A wooden bow is made from strong and flexible local shrubs and monofilament twine. A metal arrow is used as the wounding part. When fish are spotted, the fisherman sets the arrow on tension and releases it onto the fish. This method demands expertise. Commonly caught fish are belonids, carangids, lethrinids and lutjanids.

b. Spear: This consists of a metal wounding part with three to five spikes and is fitted to a bamboo pole of 3 to 4 m. The fishermen stands motionless in water and waits for surface - swimming fish. When the fish causes ripples, the spear is thrown at it. This method demands expertise and is usually operated during day time.

C. FISHING METHODS OF THE GULF OF MANNAR REGION

1. Entangling gear: These are gill nets that are operated close to the fringing reef or on reef flats. Nets are usually anchored and have a mesh size of 2 to 6 cm with height of 1.5 m. Nets with greater height (3 to 5 m) are operated in deeper waters off the reef by one or two canoes and 4 to 6 fishermen. Operation is usually conducted at night. Fish that are commonly caught are acanthurids, carangids, lethrinids, lutjanids, mugilids and scarids.

2. Falling gear: These are the common cast nets with or without strings and close pockets operated on shallow even rocky surface or on reef flats around Gulf of Mannar Islands.

3. Line fishing: Simple hand lines that have already been described are popularly used. The most commonly used bait is squid. They are either operated from the shore, exposed rocks or from country craft. Bottom set long line units are operated adjacent to submerged reefs or sandy bottoms. These units are 100 to 200 m long with short snood lines at intervals of 3 m and sinkers intermittently placed. Small hooks of No.15 to 18 are used with squid as bait. This gear is operated by two fishermen from a country craft during the early hours of the morning (1 or 2 am) and hauled up by 6 or 7 am. Commonly caught fish are lethrinids lutjanids, serranids and occassionally carangids.

4. Seine nets: This gear involves nets that are 50 to 70 m long with 2 to 3 cm mesh size, made of polyamide material. The head rope is fixed

with floats and foot ropes with sinkers. Area of operation is normally on sand flats or occassionally plain rocky bottoms. One end of the net is kept on the shore while the other is taken into the sea and payed in a semicircular manner, and brought to the shore. The net is pulled towards the shore by about 25 fishermen. A wide variety of fish are caught as this is a non-selevtive gear.

5. Traps: A popular indegenous method of catching fishes from the fringing coral reefs, rocky and sandy bottom is by the use of locally made traps. The use of traps forms a regular and sizeable fishery in the region, specially around the Keelakarai group of islands. Traps are made of intricately woven mats, using split stems of Acacia bamboo splits or mid-ribs of palmyra leaves. The mesh is hexagonal in shape. The trap consists of a single chamber with 1 to 5 entrances; the one with 3 entrances is commonly used on reefs. The dimensions vary between 0.50 to 1.20 m in length, 0.50 to 1.00 m in breadth, about 30 cm in height. They are placed on sandy bottoms by two fishermen who carry them on country craft. The area of operation is usually 30 to 50 m away from shore in water depths between 1 to 2.50 m. About 20 traps are dropped with stones as weight onto the sandy bottom, parallel to the shore. They are interconnected with a rope that helps secure their position and helps in hauling. The traps are kept over night or at times for the entire day.

Operation on rocky bottoms involves placing the traps by skin diving at suitable areas around the islands on fringing reefs. The depths normally range between 2 and 4 m. Squid, fish, crabs and holothurians are used as baits and coral stones as weights. Traps operated in reef

areas are larger with more entrances, and are hauled up after 24 hours, usually early hours of the morning, replacing them with fresh traps. Traps are sundried every day. Commonly caught fishes are those that inhabit reefs; acanthurids balistids, chaetodontids, haemulids, holocentrids, lethrinids, lutjanids, mullids, pomacentrids, scarids, serranids and siganids.

DISCUSSION

Men have traditionally interacted directly with fishes, first as hunters and more recently as farmers (Bardach and Magnuson, 1980). Men as hunters have traditionally retained their fishing activities on remotely located island ecosystems like Lakshadweep and Andaman and Nicobar Islands. Methods used appear to have developed slowly by experience with nature and behaviour of fish over hundreds of generations, some of which have culminated in the development of modern fishing methods. In comparing the three different reef systems and the variation in number of fishing methods employed, it is evident that a greater diversity in methods exists in Lakshadweep than at Andamans or Gulf of Mannar region. A possible reason for this is the variation in bottom topography between atolls and the fringing reefs. Atolls perhaps offer a greater scope for operating gear like seine nets, drive-in-nets and gill nets while these cannot be efficiently operated on the limited expanse of fringing reefs, and steep depths. Kumaran (1973) stated that indegenous craft and gear is confined to the narrow coastal belt of the eastern coast of Andamans and the neighbouring islands. Only a negligible area from the vast deep sea

front is exploited in Andamans (Marichamy, 1974). Fringing reefs in the Gulf of Mannar also appear to pose constraints in exploiting coral reef fish. Further plain topographical areas between the main land and coral reef islands offer scope for operating other gears like trawls and could be a possible reason for the absence of traditional gears. Munro (1983) stated that use of trawls and other nets in coralline tropical seas is precluded or severely restricted by the presence of reef building corals, and in most areas methods are restricted to the use of traps and vertical hook and lines.

Another possible reason for the variation in the number of fishing methods appears to be the origin of the local fishermen population and the importance given to the fisheries sector. The main stay of Lakshadweep population is fishing and coconut production. While in Andamans, Kumaran (1973) found that fisheries occupied only a low place in the economic complex as the early settlers were mostly engaged in agriculture. The absence of sufficient number of fishermen and mechanised boats was a serious handicap in exploiting resources. Marichamy (1974) stated that only a few settlers and migrants from mainland have taken to fishing. Introduction of methods like bottom trawling, longlining, purse-seining and Kalava lines has been reported by Sudarshan (1977) but appears to be less popular.

Most of the traditional methods use the behaviour of fish for capture. As already discussed, most coral reef fishes are site-attached and sedentary. The use of covering gear (Kallumoodal) assumes that fish normally hide beneath coral boulders and scaring them results in capture.

A similar method makes use of the timing of migrations seen in nocturnal zooplanktivores. The fact that fishes like apogonids, holocentrids and pemphrids leave their diurnal shelters is perhaps well known to local fishermen. Although most nocturnal planktivores feed near their shelter sites, many migrate to feeding groups elsewhere (Hobson, 1991). The mid-night timing in laying nets on massive corals perhaps allows sufficient margin for fish to migrate out and removal before dawn is perhaps to prevent fish from relocating themselves into new habitats when they realise that they are captured. The use of a coloured net is to camouflage with the surrounding habitat.

The open arms that guide fish into collecting chambers in case of Chaal and Padhi make use of the fish movements with incoming or out going tides, that otherwise take place through naturally occurring passes (relatively deeper connections between lagoons and outer sea). Johannes (1980) observed many species which occupy reef habitats during low tides move up onto seagrass beds in the lagoons to feed during high tides. A reverse process must obviously be true, and is made use of by Padhi. Blanchet (1985) reported the construction of similar family owned traps on Tikehau atoll and stated that 'Chicken mesh' is used instead of coral piles that were used earlier. Further, he mentioned that this is an ancient method practiced in south Pacific islands, Indonesia and Philippines.

Setting gillnets across boat channels, seagrass beds and passes (deeper channels on shallow reefs) also perhaps make use of regular migration routes of fishes on coral reefs. The Kandalivalai described from

the northern islands of Lakshadweep differs from a similar composite net operation reported by Jones and Kumaran (1959) from Minicoy Island, in the sense that palm leaves act as a scare line that drives fish closer to the seine net and not as an aggregating device. Further, Bala-jaha described by Jones and Kumaran (1959) is dragged onto the shore after aggregated fish are encompassed but the other method involves encompassing by two other smaller-meshed nets without being dragged onto the shore. Thus, it is evident that the 'aggregating habits' and 'fright habits' of coral reef fish are used in similar methods. Fishes with different habits were found to be included in varying the time of operation (day/night) and place of operations. For example, feeding aggregations of fishes on seagrass beds at high tides (Johannes, 1980) are likely to be caught by seine nets operated on this zone. The logic of timing seine net operations with tides is perhaps applicable to operations in Andamans and Gulf of Mannar region also.

Encircling nets operated for pelagic tuna-bait fish and hemiramphids make use of their exclusive surface swimming character. Nets are not pursed from beneath as these fish do not nose-dive and evade the net. These nets also make use of habitat associations of demersal coral reef fish, when they are encircled around a coral boulder. The Chilla also wounds surface swimming fishes.

Due to the abundance of fish on coral reefs, gill nets can be very successful in most areas. The use of large gill nets operated outside the reef seems to be limited in Lakshadweep. A possible reason could be the one proposed by Murno (1983) for the Caribbean region, where the

technique seems to be limited by damage as a result of contact with coral reefs or due to presence of sharks. In the present investigation, a 15 day night gill net operation on the reef slope yielded sizable catches, but there were occassions when the net was washed up onto the reef crest due to an unstable anchor on a sloping reef contour, when the catch was eaten by sharks, and when the net was torn badly perhaps due to large sharks that escaped after entangling. The fringing reefs of Andamans may be safer for gill nets due to very steep reef slopes and protected channel zones. Marichamy (1974) reported good catches by gill net operations.

The unique method of Idupumanakam is perhaps based on spawning aggregations or migrations along the reef. Johannes (1978) found that, as a result of predictate concentrations in space and time and in some species, their unusual docility, reef fishes are particularly vulnerable to fishermen during their spawning periods.

Catching sharks with hands seems to be an easy task for experienced fishermen. It is a well known fact that sharks swim with their dorsal fins out of water when they surface and their position around floatsams is normally well below the tuna schools. Fishermen convert this heirarchial position of fish in zones into heirarchial fishing. Shark which is a secondary predator on a food chain is not disturbed but tunas (primary predators) are caught first. Powerful olfactory senses of sharks are tapped by tuna blood to surface them. Unlike other fish, a non-slimy body and rough placoid scales enable catching sharks by hands.

Dynamiting and use of poisons are not used as fishing methods among Indian coral reefs. However, fish poisioning is popular in Lakshadweep and Andamans and is environment friendly. The use of material from plant origin remains common but the process affecting the fish seems to differ. In Lakshadweep the intoxicant is given along with bait while in the Andamans the water medium is mixed with the intoxicant.

Certain fish are attracted to light (flyingfish), some are excited (belonids) and some are stunned (both diurnal and nocturnal fishes). Light fishing methods use these behavioural responses when fish are most vulnerable. The lift nets or the dip nets (Nilamahi-dou of Minicoy) described by Jones (1958) and by the present investigator can perhaps be efficiently used with lights to aggregate fish that are active at night. A method similar to this consisting of stick held dipnets mounted onto pole-and-line vessels aggregate bait fish using submersible lamps (1 to 15 KV), concentrating them by subsequent dimming effect and surfacing them by raising the lights (Dazzel and Lewis, 1989).

In collecting fishes at night, the following advantages can help the tropical aquarium fish industry.

1. Effortless capture of both diurnal and nocturnal fishes due to stunning.
2. Low state of stress in diurnally active fishes due to reduced rates of metabolism during rest periods.
3. Reduced physical damage enhances post-capture performance.
4. Greater number and variety can be collected.
5. Lower environmental temperature reduced local transportation and handling stresses.

6. As extensive chasing or following fish among habitats is reduced by this method, habitat damage is least.

Trolling has gained popularity in Lakshadweep, in which the main catch is tuna. The method has been modified by local fishermen by varying the colour of the lure with regard to bait colours that naturally occur in water in a particular season. The use of red and white cloth pieces in Andamans has been reported by Sen (1973). Kumaran and Gopakumar (1986) reported that surface trolling is conducted with two troll lines but in the present study, four lines were found to be commonly used. Further, direct cruising observations indicate an inefficiency of the 'pablo' boats in reaching tuna schools for trolling (also for pole-and-line fishing). It appears that the mainland pablo boat design normally used for trawlers does not suit pole and line or trolling boats where speed is of prime importance. This is prooved by the inhabitants of Minicoy who obtain these boats and restructure them into a streamlined boat or are currently building their own boats. A simple example of the Maldivian fishing industry, is worth examining; traditional boats have never been given up; instead, mechanisation has been introduced only with slightest modification to accomodate an engine.

Variation in baits used sometimes resulted in species specific catches. This reflects the feeding habits of fishes. Kyphosids can be captured using seaweeds while Lutjanus gibbus can be obtained by using intertidal sipunculids. Marichamy (1974) reported that hook-and-line fishing in Andamans resulted in about 30% of the total landings (1968-70) with perches being the major catches, while Munro (1983) found it to be

the second most important method of exploitation of reef fishes in the Caribbean region. Due to high fish biomass and intense competition for food, fish immediately responded to any bait. Though this method is practiced in Gulf of Mannar, it appears to be popular only among small fishing units. Long lines are less popular in Lakshadweep and the main draw back is the lack of suitable craft. They are currently being operated from tuna-pole-and line mechanised boats.

Munro (1983) found that use of traps for capturing reef fishes and crustaceans is the predominant feature of the Caribbean reef fisheries. This method makes use of the habitat - specific nature and a continuous quest for food of coral reef fish. Traps with baits provide this requirement. Trap fishing was found to be a regular fishery only in the Gulf of Mannar region, perhaps because the fringing reef is suitable only for such gear. Hignette (1979) recommended using traps as one among the fishing techniques that can be adapted based on the biotope. The position of the traps facing the lagoon in Lakshadweep was similar to the one reported by Morize (1984) who stated that largest captures were obtained in this manner, presumbaly on out going fish. However trap operations are almost extinct in Lakshadweep. It may be worthwhile to revive trap fishing in this region for obvious reasons. In the present study, an intensive search could only spot two traps, one in Kalpeni and one in Chetlat. They also seem to be less popular in Andamans.

Spear fishing was observed to be most popular in Andaman Islands perhaps due to the tribal race, while in Lakshadweep, it is slowly dwindling. The spear fishing for seerfish uses a unique lure to which the

predator is attracted. Fishermen have perhaps observed seerfish chasing flyingfish more often than other prey fish and thus use its model as a visual cue to harpoon the fish. In describing the feeding phases of fish, Atema (1980) stated that it consists of an appetitive phase and a consummatory phase. The former consists of identification and location. It is perhaps this phase that the fishermen aim at to lure the fish to surface and harpoon it before it attains the consummatory phase. Atema (1980) further observed fishermen to adapt lure similar to the visual environment and the appearance of the prey their fish are hunting.

Fishing methods operated on coral reefs are diverse and unorganised. Most of them are traditional and dependent on the biotope. Some traditional methods and fishing in general is dwindling in Lakshadweep due to the impact of provision of land based government jobs. For example, the least number of tuna boats are now found in Kalpeni Island and fish hardly reach a few families. Care should be taken not to overexploit particular resources. Certain fishes that have market demand (e.g., Epinephelus spp., Plectorhinchus orientalis, Variola louti) can be subjected to over exploitation.

Most fishing techniques on coral reefs tend to target the larger individuals in the population and so fishing would thus be expected to reduce the number of large individuals (Russ, 1991) while large predatory fishes (lethrinids, lutjanids and serranids) had greater biomass on unfished areas compared to heavily exploited inshore reefs (Munro, 1983). However, the present study indicates an enormous scope for planned development of traditional fisheries and utilization of the vast underexploited coral reef fish resources.

CHAPTER VII

RESEARCH RESULTS RELEVANT TO DEVELOPMENT AND MANAGEMENT OF CORAL REEF ECOSYSTEMS OF INDIA

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The numerous species of fish present on a coral reefs make this habitat rich/richer than any other environment for fish on earth (Sale, 1991 a). Presumably, since man first discovered coral reefs, he has devised means of harvesting their productivity and diversity and one of the major food resources on coral reefs are fishes (Salm, 1988). In terms of mobility, accessibility and temporal and spatial scale of processes - coral reef fishes are an excellent system with which to work (Sale, 1991 a). In this chapter, attempts have been made to relate the results of research of the present investigation to development and management of coral reef ecosystems in Lakshadweep and other regions harbouring such ecosystems in the country. This account follows the pattern of organisation of chapters dealt with in the thesis.

Sub-habitats on coral reefs:

At scales of hundred of kilometers, reefs are scattered across the tropical seas and at smaller scales they offer a series of habitat zones distinctive in physical and other features, and within each zone, at scales of meters there exists a patchwork of physically distinctive sites due to differing coral morphologies and intermixing of coral colonies with rubble, sand and limestone (Sale, 1991 a).

Classification and study of sub-habitats and their diversity can indirectly predict the richness of fish species on respective habitats as they are intimately attached to their habitat. For example, the low habitat diversity is well correlated with lack of coral reef fishes in the Gulf of Kutch region. Fishelson (1980) postulated that, the more variables (diverse) that comprise the habitat, the more users (fishes) will be able to utilize it. Knowledge on the structure of the habitat will enable designing gear that is suitable to the particular biotope and avoid damage during operation. The structure of massive coral zones and live corals was found to be such that they can damage nets while traps can function efficiently. Gill nets can be operated on sand flats and seagrass beds.

The sub-habitat diversity can further speak about total reef health as these small components collectively comprise the entire reef system. A marked decrease in the variety of sub-habitats (e.g., Gulf of Kutch region) can indicate dwindling reef health which calls for immediate conservational measures. The knowledge of pre-existing sub-habitats can help partly in rejuvinating reef structure through artificial means and subsequently restore

reef fish populations. Fishelson (1980) stated that the first steps in increasing space supply have been taken by construction of artificial reefs, especially in shelter-poor habitats. Pillai (1986) found that the visible changes brought about in the environment (Minicoy lagoons) is of prime importance in the decline of live bait and the intensity of coral growth determines the settlement of fish.

Therefore, in such ecologically depleted environment there is a chronic need for space. Fishelson (1980) stated that by providing new retreats, fish biomass can easily be raised. An ideal example is provided by a habitat improvement measure undertaken by the fisheries department in Minicoy, where stacked rubber tyres on barren sand flats yielded at least 100 individuals of Lutjanus kasmira and L. bengalensis taken by hook-and-line in an hour's time.

Results indicate that seagrass beds on Kavaratti are well established nurseries and are susceptable to damage by seine nets. Disturbance to such habitats could result in a decline in the steady supply of sub-adults onto adult-reef-habitats after transforming from their juvenile stages. Closure of activities on certain areas could perhaps increase fish biomass. Further, depleted areas or barren sand flats can otherwise be made efficient as nurseries by establishing artificial seagrass beds. Artificial seagrasses can be produced from inexpensive or recycled polymeric materials, and anchored on the bottom at optimal sites (Fishelson, 1980). Without seagrasses, shelter will be lacking or greatly reduced. Without shelter, the settlement success of juveniles will be

reduced (Bell et al., 1987). Reef and position of sub-habitats can help in locating suitable spots for various mariculture activities like pearl, seaweed, sea cucumber and cage culture of fish in the lagoonal zones, and for tourism purposes where intricately growing reefs impart aesthetic value.

2. Distribution of fishes in the coral reef ecosystems of India:

A comprehensive list of fish species belonging to selected families inhabiting different coral reef ecosystems finds its use in forming preliminary bases for bridging gaps in the biogeography of certain species. Thresher (1991) found that ranking of families at each site in order of species richness provides more details about the geographic affiliations among sites. He used 21 checklists of species from sites in the Indo-Pacific and western and central Atlantic to test for geographic trends in the species composition of their assemblages. It was clearly evident from this that data from the Indian region was not included. Therefore, compact checklists form basis for further detailed taxonomic works.

Regional availability of candidate species for mariculture or capture fisheries can be identified by using such information. The overall species composition of fish of ornamental value from the Indian region (e.g., Acanthuridae, Chaetodontidae Pomacanthidae, Pomacentridae etc.) can be utilized in the preparation of market information with regard to price and strategies to harvest or transport them. Further, the regional availability of high food value fishes (e.g., lethrinids, lutjanids and serranids) can be pointed out. Finally, variations in species composition between geographic

areas brings in an understanding on suitable environmental conditions for reef fish, that in turn can be used for formulating conservational measures. However, two to three year-long field studies are not sufficient for any species and generalizations about the factors determining the composition and dynamics of geographically diverse reef fish assemblages should be assayed with caution (Thresher, 1991). In this connection, the data in the present study provide only a limited base for obtaining non - generalized information on the habitat and comercial utility of fish species.

3. Coral reef fish community organisation:

An understanding of the nature of reef fish assemblages and of the processes responsible will be of direct benefit to managers, both those who manage reef fisheries and those who manage reefs for tourism and other purposes (Sale 1991 b). Basic data and patterns of fish assemblages can be ranked according to their richness in family or species coposition on sub-habitats; this would help in locating areas of abundance of fish on the entire reef system. For example, from the results of the present study, one can expect to find a greater fish diversity among massive corals. Knowledge on characteristic fish associations listed on sub-habitats in the present study, their species compotion can be used to selectively operate fishing gear in the particular habitat zone. For example, chaetodontids needed for marine ornamental fish trade cannot be expected to inhabit sand or rubble in great abundance but can be found among live coral and massive coral zones. Similarly, fishes of food values inhabit zones where their preferred food would be found in abundance (e.g.;

scarids and acanthurids are herbivores and they may be found on seagrass beds). The fact that fish species utilize different spaces and shelters can be utilized for fish management in mariculture including stock maintenance and increase of yield (Fishelson, 1980). Differences found in assemblages of fishes with seasons can be used to time fishing operations on a particular habitat. Conventionally monsoons are favourable for fish spawning but Lassig (1983) observed the disappearence of reef fish due to severe storms. Periods of avoidance of certain habitats by fish, evident from the present study, can be used to plan fishing operations.

Though nocturnal fishes were poorly represented in the censuses, a gross idea can be obtained about their presence based on occasional clues given by their appearence (e.g., on massive coral zones). Some of them (apogonids) form important bait for tuna fishing. Precise knowledge of their assemblages could help in operating certain gears specific to them. The site specific nature of coral reef fish can locate desired species immediately for the marine ornamental fish trade. Some of the highly priced species like Pomacanthus imperator or P. pygoglites were found on the reef slope. The cleaner wrasse can be effeciently put to work in cage culture systems to perform a part of grow-out maintenance in removal of parasities by utilising its feeding behaviour. But the species may not function well without being attached to a habitat. Therefore, knowledge on its specific or desired habitat obtained by field observations will enable managers to provide a miniature coral piece in the cage to enhance its function. A territorial attachement to a site has been reported by Robertson and Choat (1974).

Tropical fish trade has become increasingly popular especially in the temperate countries (Andrews, 1992). Wood (1985) suggested that exporting countries should be able to assess the status of their reef fish populations to manage the resources. The assessment would therefore certainly weigh studies on community organisation of fishes on a priority basis before implementing management measures. Stress is one factor that causes various behavioural changes and such reactions are particularly evident in aquaria (Henderson, 1980). Mortalities are encountered at various stages between capture and retailer premises and finally a hobbyist in the case of ornamental fishes. The knowledge on community organisation on sub-habitats in the present study would help provide conditions (habitats) simultating natural environment of the species. Further selection of apt tank mates based on natural community association or species association on a particular sub-habitat can successfully build up a compatable community within the tank and reduce competition and mortality.

Fish being relatively more complex organisms, many aspects of their biology and behaviour may be used to gauge the degree of 'suitability' of their habitats. Certain species of chaetodontids which are obligate and coral predators are considered as 'indicator fishes' (Reese, 1981). It is to be hoped that ecological research identifies indicator species or families which when monitored can be assumed to give a reasonable indication of the changing habitat through changes in population levels (Gomez and Yap, 1988). Therefore, aspects of community organisation of reef fishes can be utilized in implementing conservation measures and obtaining subsequent feed back on the effectiveness of methods

employed. For example, the diversity of Chaetodon trifascialis and C. trifasciatus compared between healthy reefs and impoverished reefs can indicate reef health. Further, the monitoring of species diversity and abundance with time will reflect on the status of fish resources as overexploited, underexploited or optimally exploited. Russ (1991) stated that direct effects of fishing at the community level involve effects of removal of predators, prey or competitors from communities of fishes.

The community organisation of fishes finds its way into some of the non-extractive uses derived from coral reefs. Reef based tourism has become increasingly popular in the recent years at Lakshadweep and Andaman Islands. Salm (1988) states that fish watching as a sport and underwater photography have grown in popularly replacing fishing and spear fishing among the recreational activities. Local residents are generally slower than tourists to use coral reefs for recreation (Salm, 1988) but information on characteristic fish assemblages provided in the present study can obtain small incomes through guidance of tourists to species-rich spots. In the field of education, coral reefs are natural laboratories which provide invaluable opportunities for observing living examples of various principles taught (Salm, 1988) and fishes being a dominant group with diverse mechanisms of coexistence, form attractive subjects for ecological studies.

4. Food and feeding habits:

Studies on the food and feeding habits of 143 species of coral reef fishes in the present study help the fisheries sector in many ways.

Normally, very few fishes inhabiting coral reefs (especially carnivores) have the scope of being utilized as mariculture species or as commercial fishing targets. Food partitioning is more common than food sharing in carnivorous fish (Fishelson, 1980). As diet differences exist between species in a single family, the candidate species chosen can be based on the local availability of its prey. In certain cases, carnivorous fish are opportunistic (Goldman and Talbot, 1976) and in such instances fish with greatest adaptability to food changes can be chosen. However, apart from food preferences, there are other factors (e.g., market demand) that dictate the choice of a particular species.

Knowledge on food habits help in providing the fish with its desirable food item; the collection of food depends on clues provided by natural habitat associations of fish. Given apparent correlations between distributions of species and their food, habitat selection for areas of greatest availability of preferred food is a likely proximate factor in determining distributions (Williams, 1991). Discussions on community organisation has at many places correlated their distributional patterns to food availability and this can be used to locate a particular species in relation to food.

One reason for low survival of marine ornamental fish in captivity could be the lack of natural food and their slow adaptation to forced consumption of artificial food. Depending on the feasibility, artificial diets can occasionally be supplimented with natural feeds for which the information on food habits of coral reef fishes can be used. Alternatively,

the choice of fishes with easy adaptation to change in food habits should be selected. For example, pomacentrids can be easily adapted to feed on particulate organic matter (e.g., shredded meat) while chaetodontids that are specific feeders pose constraints. Problems of specific food preferences can be overcome by using 'taste enhancers' on artificial feed. Derivation or replication of specific taste imparting compounds can be attempted with knowledge of preferred prey indicated for many species. Atema (1980) suggested that both odour and food flavours can be potent long-term feeding enhancers. This could be applied to a variety of other fish intended to be kept under captivity or used in mariculture. For example, a majority of benthic carnivores were found to have fed on crustacean based diet, and formulation of feed enhancers based on crustacean extracts could be common to many reef fish. Finally, the proximate nutritive composition of prey items can help in formulating balanced diets for mariculture purposes.

In capture fisheries, the knowledge of food habits can help in providing specific bait based on specific prey preference of species to obtain species-specific catch. Though this study considers only common reef-associated fish species, the application of odours in enhancing capture of tuna is suggested as it forms a major fishery around island ecosystems. In view of reports based on decline of bait fish (Pillai et al., 1986), the bait fish can perhaps be efficiently substituted by artificial attractants formulated based on food of tunas. The basic principle employed in the capture of tuna is to create a 'feeding frenzy' when the fish fails to differentiate between a hook and its bait. Casual observations during the

present study revealed that skipjack (Katsuwonus pelamis) responded to pole-and-lines without bait. Two situations are evident causative factors, one is that tuna in the area are pre-existing feeding schools and fishemen only take advantage of natural bait; second, the hungry tuna schools are chummed only by water-splashing. Atema (1980) mentioned that tuna was found to show general excitement when they percieve food odours. The use of attractants by spraying, if successfull, can reduce expenditure on fuel, time, efforts in capturing and maintaining bait fish alive until fishing grounds are reached. Further, attractants can be less space occupying in the sense that they are low-volume high-effect substances (like commonly used perfumes). From the point of view of conservation, habitat damage during bait fish fishing can be minimised.

The corallivorous habit of certain specific chaetodontids can indirectly denote the health of the reef (Reese, 1981). As already discussed earlier, such assemblages provide a useful tool in conservation and management by measuring their abundances. Strict corallivores were found to feed on low proportions of algae which can also reflect on dwindling resources of their preferred prey. Therefore, the process of slow adaptation towards a change in environmental conditions can also be used in conservation and management.

5. Reproduction:

Studies on maturity and spawning provide a basis for effective management of the multi-species stock of fishes on coral reefs. Large and valuable amounts of information on reproductive timing could be gained

inexpensively within a year by monitoring the state of maturity of fish (Johannes, 1980). The size at first maturity of males and females can be used to obtain information, on which other uses like size selection of species for induced breeding and length regulations for fishing in case of overfished stocks can be based on. Many families of fishes have members which are sequential hermaphrodites (e.g., labrids, lethrinids, pomacanthids, pomacentrids, scarids and serranids) (Russ, 1991) and this was pictured through the sex-ratio patterns of certain labrids. Fishing methods are normally targetted towards large individuals. In a protogynous group, where males are less, but large, their removal from the group could hamper reproductive success. A continuous monitoring of sex-ratios and fecundities of commercial catches of reef fishes in regions of intense fishing could help in formulating management measures.

The knowledge on spawning frequency and spawning seasons can help in both underexploited and overexploited cases of fisheries. For exploitation, first step is to identify spawning times, and using this the spawning locations can be spotted for exploitation. Johannes (1980) stated that predictable spawning aggregations of reef fish at specific sites are widely used opportunities for fishermen to make large catches. In contrast to exploitation of an underutilized resource, information on maturity and spawning can be used to implement managerial measures to reduce overfishing if any, by reducing catch on spawning grounds. There is evidence that unusually bad weather may interfere with the seasonal timing of spawning of certain reef food fish (Johannes, 1980). The characteristic avoidance of southwest monsoon seasons for spawning in many fish from

Lakshadweep could help in timing harvests without affecting recruitment. Knowledge of spawning seasons could further help in predicting subsequent juvenile abundance on reefs or use the information for trials on induced spawning, especially for rare ornamental fish that are in great demand. Among several recommendations made by Wood (1985) setting up of captive breeding programmes can help overcome overexploitation.

Juvenile settlement can be maximised by ensuring that seagrass beds which act as nurseries are not disturbed. Studies on the composition of juveniles on seagrass beds can identify the presence of desired varieties of species suitable for culture operations (e.g., siganidae, serranidae, carangidae etc.) and period of their abundance. As larval stages in general are extremely difficult stages to rear, their association with seagrass beds is advantageous as these critical stages are taken care of. Seed can be collected after they tide over their critical phases. If there are extensively fished habitats in the vicinity, Fishelson (1980) stated that seagrass beds would serve as sites which could supply individuals for repopulation of extensively fished habitats. Based on the information obtained on the occurrence of sub-adults of species of ornamental value, they can be rationally harvested for the marine ornamental fish trade, as smaller individuals can be easily transported. The timing of maximum settlement of juveniles in the present study was found to be in summer and this can be avoided for the purpose of conducting any developmental activities in the vicinity of the habitat.

Fishing methods:

James et al. (1989) identified fish resources other than tuna in Lakshadweep and suggested development of fishery based on such resources. This can be undertaken by sufficiently improving various fishing methods in vogue. Among various methods described, gears like hook and line in Andamans (Marichamy 1974) and perch traps in the Gulf of Mannar region (Prabhu, 1954) are very successful on reef systems. The reason for decline of the use of traps in Lakshadweep in this context remains unclear. Both hook-and-lines and traps make use of two important resources (food and shelter) that coral reef fish continually seek. As Hignette (1979) stated that fish catching techniques must be adapted to their biotope, these methods seem to have enormous scope of development in raising fish yields. They are environment friendly and cause relatively less damage to the ecosystems, and are more or less passive gears involving comparatively less capital input. In a socio-economic study of small-scale fishing in the atoll of Tikehau, Blanchet (1985) described how an artisinal fishery using traps (similar to Chaal and Padhi) has been upgraded by replacing coral stones with chicken mesh. Munro (1983) reported that traps followed by hooks and lines form the most important gear in harvesting Caribbean reef fish resources. Gill nets are also efficient passive gear but a thorough study on orientation of the gear on reefs with respect to currents is necessary to avoid damage.

The traditional use of lights to attract or stun fish can be effectively used by modification of light source and vessels. The methods used in the south-Pacific for obtaining tuna bait using electric lamps

(Dazell and Lewis, 1989) can be efficiently used on Indian reef systems. Apart from the two responses of attraction and stunning, a third reaction of agitation in response to light has been observed in belonids. This behaviour can be used to locate their positions before nets are payed around them. Introduction of troll lines has been successful after mechanisation in Lakshadweep but observations indicate that there are serious drawbacks in the 'pablo' boat design used. An improvement in craft design taking Maladivian mechanised boats and modified boats in Minicoy as case study material could help augment catches.

As already mentioned in Chapter VI, fish catching methods employ various behavioural patterns of reef fish. Therefore, it is necessary that any attempt towards development of capture fisheries should possess or study the behaviour of fish in relation to local topography.

This study is only a beginning in the study of coral reef fishes and their habitats. Our understanding of fish and fisheries in the seas around India has made significant strides, leaving coral reef ecosystems far behind, despite their current global importance. Therefore, there is an urgent need to channalize efforts for a better understanding of coral reef ecosystems to use, maintain and protect them for posterity.

SUMMARY

This thesis entitled **"Studies on some aspects of biology and ecology of coral reef fishes of Lakshadweep with observations on other coral reef ecosystems in the seas around India"**, embodies results of investigations on coral reef fishes and their habitats carried out from January 1991 to June 1992 at Lakshadweep with observations on the coral reef ecosystems of Andaman Islands, Gulf of Mannar and Gulf of Kutch. It deals with classification of sub-habitats in the four reef systems and associated species composition, community organisation of the reef fishes, food and feeding habits, reproduction and fishing methods. Inferences on the practical application of the results with reference to capture and culture fisheries are also incorporated.

The community organisation of coral reef fish deals with assemblages of reef fishes on Kavaratti atoll under two taxonomic categories, namely, the families and species ennumerated by visual censuses on each of the habitats and reef slope giving details on their frequencies of occurrences, abundances, species compositions, species diversity (H') and evenness (J'), seasonal variations in community parameters and distribution of each family or species with respect to sub-habitats. The two biological aspects investigated include the food and feeding habits and aspects of reproduction. Qualitative information based on prey preferences of 143 common species of coral reef fishes belonging to 30 families mainly from Lakshadweep and few from Gulf of Mannar is provided, while aspects of reproduction for 25 commonly occurring species are covered. The importance of seagrass beds as nurseries for juveniles was studied based on nocturnal collections juveniles. Methods used for capture of coral reef fishes are briefly described.

Sub-habitats on the Indian coral reef ecosystems:

The greatest diversity in number of sub-habitats (10 nos) was found in Gulf of Mannar region. The sub-habitats are zones made up of dead coral, Enhales acoroides (seagrass), live coral, mangroove roots, massive coral, Pemphis acidula (intertidal shrub), rubble, sand, Sargassum spp. (seaweed) and seagrass. Next in sub-habitat richness (8 nos) was Andaman Islands that recorded zones consisting of dead coral, live coral, mangrove roots, rock, rubble, sand-mud, seagrass and soft corals. The seven sub-habitats classified on the coral atolls of Lakshadweep are zones consisting of live coral, massive coral, rubble, sand, seagrass and boulder zone. The slope was not considered as a sub-habitat but this physiographic zone on coral atolls is a combination of characters dervied from many sub-habitats coupled with greater water depth. This zone was studied in relation to the most abundant fish species diversity that it supports. The least sub-habitat diversity (5 nos) was found in the Gulf of Kutch region consisting of non-typical reef habitats which are remains of a damaged environment. The fringing reef systems have a greater diversity of sub-habitats but with lesser individual expanse while atolls of Lakshadweep have fewer-sub-habitats but each of them with wider expanses.

Distribution of fishes in the coral reef ecosystems of India:

The 26 families selected for this study comprised of 421 species of fishes. During the course of this investigation, 12 new records were identified from Lakshadweep, 3 from Andaman Island and 19 from the Gulf of Mannar reefs. However, 9 of them were found to be new distributional

records for the entire Indian region for which detailed descriptions are included. The new records are Neoniphon opercularis (Valenciennes, 1831), Sargocentron praslin (Lacépède, 1802), Plectorhinchus gaterins (Forsskål, 1775), Chaetodon oxycephalus Bleeker, 1853., Forcipiger longirostris (Broussonet, 1782), Apolemichthys trimaculatus (Lacépède, 1831), Labroides bicolor Fowler and Bean, 1928, Scarus rubroviolaceus Bleeker, 1847 and Siganus luridus (Rüppell, 1828).

The most speciose families were Labridae and Pomacentridae that recorded 55 and 53 species respectively. The available information on coral reef fishes of India shows that relatively, Lakshadweep received considerable attention. Similar attention was not paid to coral reef fishes inhabiting the reefs of Andamans and Gulf of Mannar and the few reports existing are scattered. Gulf of Kutch received the least ichthyological activity. However, intensification of efforts in the Gulf of Kutch region is not likely to yield good collections due to an almost dead environment. Factors identified as possible determinants of distribution are the geographic variability and type of reef system, dependence of fish species on particular shelter sites and food resources.

Coral reef fish community organisation on Kavaratti atoll:

Among the fish families on the sub-habitats, Labridae emerged as a generalist family found on all sub-habitats except on live coral zone. Subsequent positions were occupied by other families characteristic of particular sub-habitats, reflecting primarily the feeding mode, site - attachement and other habits. With an exception on sand flats where only

Labridae and Acanthuridae were dominant, 3 to 5 families forming a collective list consisting of Acanthuridae, Balistidae, Chaetodontidae, Labridae, Mullidae, Pomacanthidae, Pomacentridae and Scaridae were dominant on each sub-habitat.

Equal number of families (27) represented on the reef slope and seagrass beds is because the latter has juvenile and sub-adult representatives of most adult reef fish fauna which inhabit other habitats. This was followed by 26 families recorded on the massive coral zone. As the live coral zone is composed of a single species of ramose coral (Acropora formosa), very few families (14) made use of the zone, while a similar pattern was evident on rubble zone (15 families). Despite featurelessness, the sand flats supported 17 families. The community diversity (H') was highest on the reef slope (3.32) followed by massive coral, sand flats, rubble, seagrass beds and live coral (2.96, 2.69, 2.68, 2.49 and 1.84 respectively).

Family assemblages on the sub-habitats and the reef-slope were not stable between censuses and pre-monsoon, monsoon and post-monsoon seasons. Inherent behaviour of fish connected to modes of feeding, reproduction, shelter requirement and local migrations determined the variation in the observed assemblages. Non-biological factors like habitat structure, proximity to other species - rich areas and the southwest monsoon also influenced family composition on sub-habitats. When the distribution on all sub-habitats was considered, it was found that only few families exhibited a wider niche while a majority of them were restricted in distribution.

Though the family composition was almost constant (26 to 27 families) on the reef slope, massive coral and seagrass beds, the sub-habitats showed a marked variation in species richness which was evident from the species assemblages. The increase or descrease in species composition was contributed either by greater number of genera or species supported by a single family or vice-versa. The possible cause for this pattern was that an increased topographical complexity may harbour a greater number of users of a particular sub-habitat. A high species diversity on massive coral zone is due to its proximity to the species-rich adjacent reef slope, while the same in the seagrass beds is due to their role as nurseries and foraging grounds for many fish species. Fish assemblages could be roughly predicted with space.

Highest number of species observed during censuses was on the reef slope 121 followed by massive coral zones (89). Seagrass beds and rubble zones recorded 65 and 46 species respectively. While live coral zones were frequented by 39 species, the least species composition of 28 species was found on sand flats. The community diversity (H') for species on sub-habitats was highest on the reef slope (4.45) followed by massive coral (3.93). Rubble and sand flats recorded H' values of 3.58 and 3.25 respectively, while the same for live coral and seagrass beds was comparable (3.16 and 3.14 respectively).

A highly variable pattern of species assemblages was observed between censuses and pre-monsoon, monsoon and post-monsoon seasons of the sub-habitats. Many physical and biological factors within a single sub-

habitat are possible determinants of the community structure of species. Fish assemblages in the present study did not follow a definite pattern of distribution and therefore cannot be predicted with time. When individual species were considered for their habitat width, one or two species from each of the dominant family were found to be generalists. For example, Acanthurus triostegus (Acanthuridae), Rhinecanthus aculeatus (Balistidae), Chaetodon auriga (Chaetodontidae), Halichoeres scapularis (Labridae), Abudefduf sexfasciatus (Pomacentridae) were species exhibiting wider habitat ranges. All species recorded in Mullidae had wide habitat preferences. Habitat selection in these diurnal fishes highly correlates with their requirements of food and shelter. It is therefore concluded that habitat complexity supported greater species richness.

Food and feeding habits:

As seen in the previous section, the utilization of habitats by reef fishes is for diverse purposes. Similarly, the types of feeding habits are diverse within the species of any single family. When food resources were common, minute differences appeared to reduce competition between species (e.g., mullids). It was evident from the present study that strict herbivorous species belong to Acanthuridae, Kyphosidae, Scaridae and Siganidae. These fishes fed on a wide variety of green, brown and red algae. Filamentous algae was a dominant prey item. Semidigested matter consisted of plant matter and calcareous sediment. In contrast to herbivorous fish species, the other feeding groups could not be categorised as zooplanktivores, omnivores, carnivores or benthic carnivores owing to a high overlap in food preferences. The zooplanktivorous species belonged to

families Apogonidae, Caesionidae and some pomacentrids. Copepods, decapod larvae, fish larvae, eggs, shrimp and megalopae formed dominant prey groups. Pomacentridae had species that were zooplamktivores, omnivores and herbivores. Feeding diversity (H') was in general high in zooplanktivores as a higher number of prey items were involved. Among the dominant omnivores were, Balistidae, Chaetodontidae, and Mugilidae that fed both on prey of plant and animal origin. It was observed that varying proportions of these prey items could stem a particular species more towards herbivory or carnivory while an equillibrium status retained their identity as omnivores. A majority of species belonging to Cirrhitidae, Holocentridae, Labridae, Lethrinidae, Lutjanidae, Mugiloididae, Mullidae, Scorpaenidae and Serranidae could not be distinguished as either strict carnivores or benthic carnivores as their diets consisted of benthic crustaceans (crabs, alpheids, shrimp, stomatopods, labsters etc), molluscs (gastropods, polecypods and cephalopods), echinoids (starfishes and sea urchins) and a wide variety of fishes, polychaetes, sipunculids and algae were also occassional food items. In comparison to all families, mullids showed the greatest tendency to feed on benthic invertebrates. Benthic crustaceans (especially small xanthid crabs) emerged as an important link in the food web concerning most species.

Species of chaetodontids regarded as strict corallivores fed on equal proportions of algae and coral polyps indicating a slow adaptation by change in food habits with change in environmental conditions.

In comparing the commonly occurring species between the two localities, viz., Lakshadweep and Gulf of Mannar, it was found that prey items in general appeared to be few in the latter region. The possible reason attributed to this is the difference in the nature of reef formation and types of varying substrata offered for a variety of prey items. Low H' values indicated a narrow/specific food requirement of a particular species while high H' values correlate with higher feeding diversity.

Reproduction.

Coral reef fishes are known to have complex reproductive strategies. Sizes at first maturity depended on the maximum size that a particular species could attain. Smaller species (e.g.; Chrysiptera unimaculata, Dascyllus trimaculatus, family Pomacentridae) matured at smaller sizes while larger species (e.g., Lutjanus gibbus, family Lutjanidae and Plectorhinchus orientalis, family Haemulidae) matured at larger sizes. In general, pomacentrids matured below 40 mm SL while some chaetodontids, cirrhitids and labrids matured at sizes ranging between 90 and 120 mm. While protogyny was prominent in labrids (Halichoeres centiquadrus, Thalassoma hardwickii and T. lunare), other species studied either matured synchronously or differentially, with males maturing earlier or later than females. Sex-ratics indicated that females were dominant in most species. Fecundity estimates varied highly due to the fact that most species were continuous spawners, generally spawning at very short intervals. The total fecundity range was 700 to 225850 mature eggs per ripe female. With a well established background that coral reef fish spawn on a daily, weekly, fortnightly and monthly basis, total fecundity per year is presumably very

high. Based on ova diameter studies most species were observed to be continuous spawners, some had small breaks in spawning while very few indicated biannual spawning. Spawning appeared to be minimum during monsoon and this is perhaps to tide over the adverse conditions during monsoon season which would perhaps transport eggs and larvae in an unfavourable direction.

Of the 28 families of reef fishes represented by new recruits or juveniles on seagrassbeds, individuals belonging to Acanthuridae and Labridae were most dominant. Schooling species belonging to Acanthuridae, Carangidae, Holocentridae, Mullidae, Scaridae and Signidae showed dumped and a variable recruitment. Non-schooling individuals were rare in occurrence. Absence of juveniles on the adjacent sand flats clearly indicated that shelter, apart from food, was an important resource that seagrass offered. Characteristic avoidance of monsoon seasons by adult spawners was reflected in a low number of juveniles during monsoon. Peak settlement was observed during pre-monsoon and post-monsoon seasons. A continuous occurrence of juveniles in different size ranges confirms the continuous spawning habits.

While juveniles of labrids showed a clear abundance during summer months, acanthurids were dominant both during pre-monsoon and post-monsoon. Though chaetodontids and holocentrids were not abundant on seagrass beds, they occurred consistently round the year. Seasonality in occurrence was most pronounced in Carangidae and Siganidae, while individuals of Apogonidae, Lutjanidae and Mullidae were moderately seasonal in occurrence. Seasonal abundance of juveniles was influenced by summer peaks in settlement, adult spawning, timing of settlement, magnitude of

settlement and local migrations. Abundance of larvae was not affected by temperature but increased with salinity. However, environmental parameters were generally stable and juvenile abundance seemed to be controlled by seasons, tides and currents. Occurrence of juveniles was found to be greater on days of new moon phases (dark nights) rather than during full moon phases (bright nights).

Fishing methods:

Fish resources of the coral reef ecosystems are underexploited despite the enormous potential in such ecosystems. Regional fishing methods varied with the type of reef system. Both indigenous and introduced/modern methods are being practiced and a majority of them make use of the behaviour of fish for capture. A greater variety of methods were observed in Lakshadweep than elsewhere. The atoll topography with extensive lagoon areas permitted the operation of many gears like seine nets, gill nets, and encircling nets. Though traps are successful on many reef systems, their popularity in Lakshadweep has dwindled almost to extinction. Light fishing and harpooning are important traditional methods. Operation of large gill nets outside the reef is less popular because of the damage caused to nets by reefs and sharks. Trolling is a popular fishing method.

As Andaman Islands are surrounded by fringing reefs the scope of operating a wide variety of gear is reduced. Hooks-and-lines yield highest catches followed by gill nets. Gill nets are operated in deeper waters and therefore the contact with the reef is minimum. Seine nets are

operated in shallow bays with sand flats. Traditional methods like harpoons, lightfishing and traps are practiced but are not popular. In general, low fishing activity was observed in Andaman Islands.

The only reef system where traps are very successful and form a major reef fishery is the Gulf of Mannar region. Indigenous traps are operated on a daily basis by local fishermen on fringing reefs and rocky areas bordering the islands or on plain sandy areas. Gill nets, hook-and-lines and shore seines are also operated. No observations were made from the Gulf of Kutch region.

Research results relevant to development and management:

Most of the countries having adjacent coral reefs have sound developmental programmes aimed at exploiting resources and conservation of the ecosystems. Such measures can only be based on research results obtained from the particular area. The topics studied under various chapters in the present study also find many direct or indirect uses. The classification of sub-habitats provides necessary back-stop for taking measures to protect nursery areas of commercially important fishes, predict richest habitats based on habitat complexity, adopt biotope suitable gear and avoid damage, identifying mariculture locations, declaration and establishment of marine parks, development of tourism and environmental awareness.

The information generated on the geographic distribution of certain coral reef fishes in India can identify candidate fish species that can be

used for capture or culture from the particular locality, ornamental fish species that Indian reef systems support, formulating projects on their trade and preparation of basic market information. Finally, such-check-lists help in bridging gaps in biogeographic studies on reef fishes.

Community organisation studies identify habitats that are species rich based on fish species diversity, provides information on species associations with particular habitats which in turn helps to direct fishing operations to such areas with suitable gear. Knowledge on specific habitat requirements helps in simulating natural conditions for fish in captivity, procurement of natural food for fishes based on clues provided by their assemblages, assessing an underexploited, optimally exploited and overexploited stock of fishes on a particular area. This further forms a basis to implement conservational and management measures. Finally, patterns of community organisation creates employment opportunities for local people to help guide fishwatchers (tourists) to ideal species rich locations and for basic education on principles of ecology, conservation and environmental awareness.

Preferences of natural food items of 143 fish species can be used to formulae artificial food, provide desired natural food for cultured and ornamental fish species. Based on preferred food items, the chemical composition of the prey can be determined to create artificial attractants that can enhance feeding in captive fish and lure fish for capture. Monitoring of the prey of indicator species speaks indirectly on the status of the environment, thus finding uses for this study in conservation and management.

Results on aspects of spawning and maturity help in monitoring the sizes of mature fish and the sex-ratios for the purpose of implementing management measures if a particular stock is overexploited or their selection for trials on breeding based on the frequency of spawning and spawning seasons, the recruitment of larvae and occurrence of juvenile fish can be predicted for seed collection in culture operations. Further, the predictable spawning locations of reef fish can be spotted and used for capture in the case of an underexploited stock, whereas the same information can also be used to regulate an overexploited stock. Knowledge on the occurrence of juveniles can not only help in seed collection for culture but also for collecting sub-adults for ornamental fish trade and declaration of protected fish nursery zones.

As the status of Indian coral reef fishery can be stated as underexploited, a knowledge of the fishing methods used can be utilized to develop efficient habitat-suitable gear to enhance fish production from such region. The success of certain fishing gear in some specific areas can prove to be successful in other areas with similar topography. As most of the traditional methods seem to be developed based on fish behaviour, it would be necessary for the developmental measures to give prime importance to such characteristics of fish catching methods.

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